PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION.

Engineering Library

ENGINEERING:

An Illustrated Weekly Journal.

MAR 6 1940

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

TEMPORARY OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 18 & 20, COMPTON ROAD, HAYES, MIDDLESEX.

VOL. 149—No. 3869 LONDON: FRIDAY, MARCH 8, 1940. Registered at the General Post Office as a Newspaper PRICE 1s. BY FOREIGN POST 1s. 2½d.

Air Receivers Buoys, Road Wagons Tanks. **TANKS** Hoppers, Chimneys, Ducting.
EVERYTHING FROM MILD STEEL PLATE.
JOHN BELLAMY
EAST 1892 LIMITED Est. 1860
MILLWALL E.14 1216

J. & E. HALL REFRIGERATION
FOR LAND & MARINE PURPOSES
LIFTS AND ESCALATORS
J. & E. HALL LTD., ENGINEERS, DARTFORD, KENT.
Telephone: Dartford 3456.
London Office: 10, ST. SWITHINS LANE, E.C.4.
Telephone: MANSION HOUSE 9811. 755

PATTERNS
B. LEVY & CO. WOOD & METAL. Osbert St., S.W.1 Vic. 1073

METAL SLITTING SAWS
GROUND FLAT STOCK
WILLIAM WARD & SON (SHEFFIELD) LTD. CENTENARY WORKS, WOODSEATS ROAD, SHEFFIELD. 712

SECTIONAL PRESSED STEEL TANKS
also
RIVETED and WELDED PLATEWORK
STORAGE TANKS, BUOYS, CHIMNEYS
BUNKERS, HOPPERS, Etc.
BROWN, LENOX & CO.
(LONDON) LIMITED.
Contractors to the Admiralty since 1808
MILLWALL LONDON, E.14
Telephone: East 0700/1 9882

LA MONT WASTE-HEAT BOILERS
Particulars from:— 677
LAMONT STEAM GENERATOR LTD.
Quadrant House, 55, Pall Mall, London, S.W.1.

FOR HIGH CLASS
PATTERNS & MODELS
Phone: EUSton 3176 (4 lines)
GEORGE WAILES & CO. LTD.
382-8, EUSTON RD., LONDON, N.W.1.
Specialists since 1855 669

SPENCER - BONECOURT
Patent Waste Heat Boilers
32, Farringdon Street, London, E.C.4. 868

LOCOMOTIVES
STEAM OR DIESEL
HUDSWELL CLARKE & Co. LTD.
RAILWAY FOUNDRY, LEEDS.
London Office: 46, Victoria St., S.W.1.
Telephone: Victoria 1133 8559

YARROW
& CO. LTD.,
GLASGOW
SHIPBUILDERS
MARINE ENGINEERS 848
LAND AND MARINE BOILER MAKERS

PETER BROTHERHOOD
PETERBOROUGH LTD.
STEAM ENGINES AND TURBINES,
GAS AND OIL ENGINES,
AIR COMPRESSORS,
REFRIGERATING PLANT,
See advertisement, Page 29 6938

SPRINGS
FOR ALL PURPOSES 688
WILLFORD & CO. LTD.,
PARK HOUSE WORKS, SHEFFIELD, 9

DREDGERS
OF ALL TYPES
FERGUSON BROS. (Port-Glasgow) LTD.
PORT-GLASGOW 626

FORGINGS.
WALTER SOMERS, LTD.,
HALESOWEN 7116

WAGONS
HURST, NELSON & CO., LTD.,
MOTHERWELL 3382

SPECIAL MACHINES
MADE TO ORDER
Parts and repairs
Erection of Plant
Millwrights work 952
THOMAS HUNT & SONS
Bridge Road West BATTERSEA, S.W.11.

LIGHTALLOYS LTD.
FIRST QUALITY
ALUMINIUM CASTINGS
ALPAX WORKS, St. Leonard's Road, Willesden Junction, London, N.W.10. Telephone: Willesden 3460-1-2. Telegrams: "Lightalloys-Phone-London."

"The machine with a BRAIN"
SCIAKY
SPOT WELDERS
SLOUGH —— 22342

Research Engineers, Ltd., Northampton Grove, Canonbury, London, N.1. Design and construction of mechanical and electrical machinery and apparatus. Experimental work of any description. We have also a department for quantity production on completion of experiments. 794

Alfred Herbert Ltd., Coventry
PAY BEST PRICES for SECONDHAND MACHINE TOOLS in good condition, by first-class makers.—Write, wire, or 'phone, and our representative will call. 'Phone 68781 Coventry. Telegrams LATHE, Coventry. W 305

HYDROJET
BABCOCK & WILCOX

RAPIER
Builders of Europe's Largest
EXCAVATORS
RANSOMES & RAPIER, LTD
IPSWICH 548 ENGLAND

CRADLEY BOILERS
CRADLEY BOILER CO., LTD., 639
CRADLEY HEATH, STAFFS.

MUREX Electrodes
625
MUREX WELDING PROCESSES LTD.,
HERTFORD RD., WALTHAM CROSS, HERTS.

MACROME
—Toughest Tools in the World—
MACROME 842
—— LIMITED ——
Hay Mills, Birmingham. Telephone: Vic. 1283
"Z Dept."

CRANES
GEORGE RUSSELL & CO., LTD.,
Motherwell. 816

INSTALL
"SIROCCO"
(TRADE MARK)
PRODUCTS FOR DUST REMOVAL & COLLECTION
Write for Publication SF380.
DAVIDSON & CO. LTD.,
SIROCCO ENGINEERING WORKS,
BELFAST. 886
LONDON : MANCHESTER : DUBLIN : CARDIFF
BIRMINGHAM : NEWCASTLE : GLASGOW : BRISTOL

WATER SOFTENING
PATERSON ENGINEERING CO., LTD.,
83, KINGSWAY, LONDON 780

Small Power Transformers for Low Voltage Lighting, etc. Coils, Solenoids Chargers. Keen prices, quick delivery and 100 per cent. reliability.—WODEN TRANSFORMER COMPANY, Thornley Street, Wolverhampton. J 851

ASH & DUST
LTD., 34, FARRINGDON

Send for NEW Catalogue
COOPER SPLIT ROLLER BEARINGS
KING'S LYNN 708 NORFOLK

TWIN DISC CLUTCHES
BRITISH TWIN DISC & CLARIFIERS LTD.,
BUSH HOUSE, ALDWYCH, LONDON, W.C.2

WATER SOFTENERS
JOHN THOMPSON
(KENNICOTT WATER SOFTENERS) LTD.,
WOLVERHAMPTON
Estd. over 40 years. 744

WATER TURBINES
GILBERT GILKES & GORDON LTD.,
KENDAL, ENGLAND. 787

TAYLOR AND CHALLEN POWER PRESSES
TAYLOR AND CHALLEN LIMITED. 718
DERWENT WORKS, BIRMINGHAM, 19.

SAMUEL PLATT
LIMITED
King's Hill Foundry, Wednesbury, Staffs.
DRAWBENCHES
FOR
AIRCRAFT WORK 699

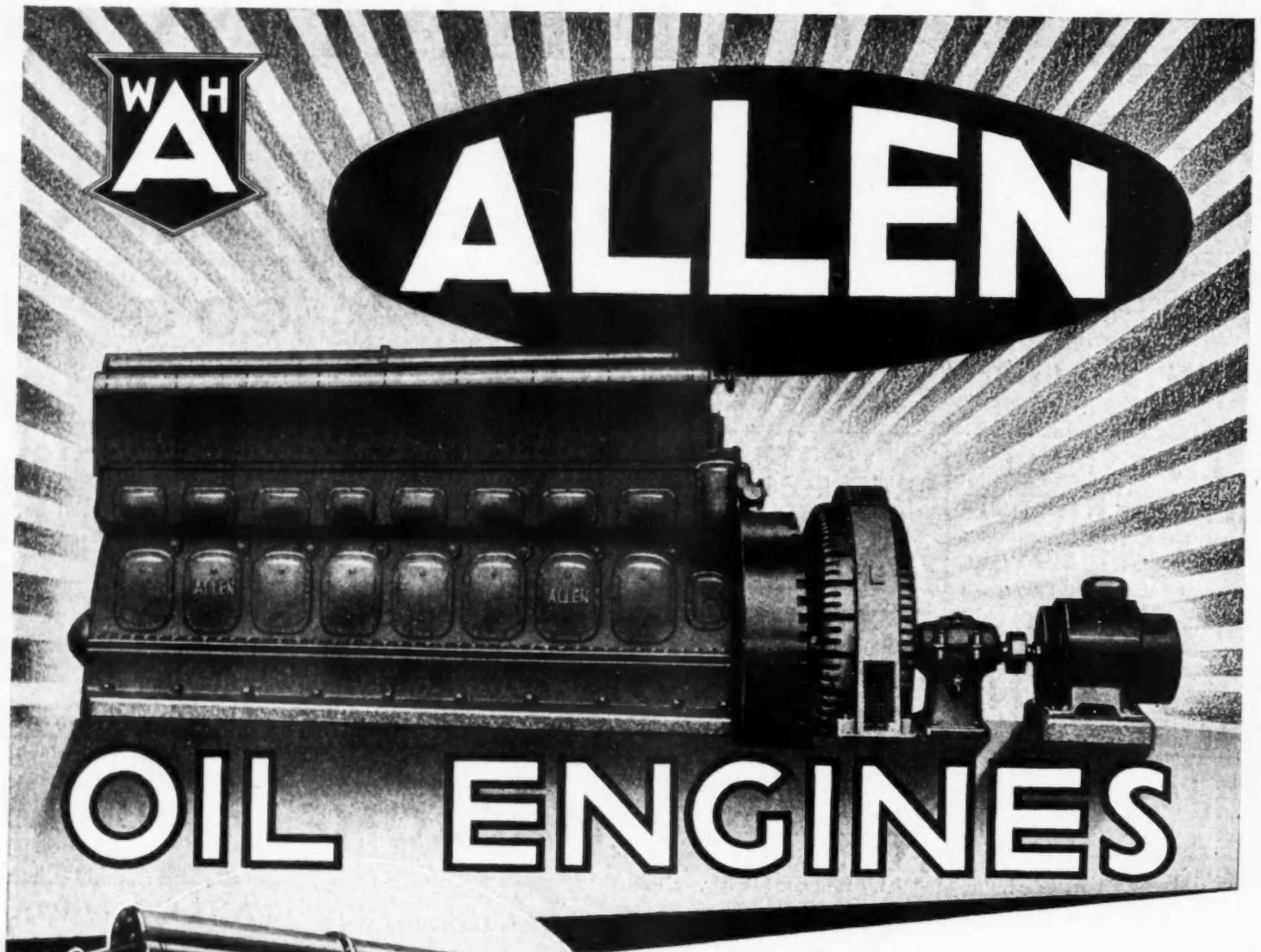
ALLDAYS & ONIONS
685 BIRMINGHAM. LTD.
SMITHY PLANT

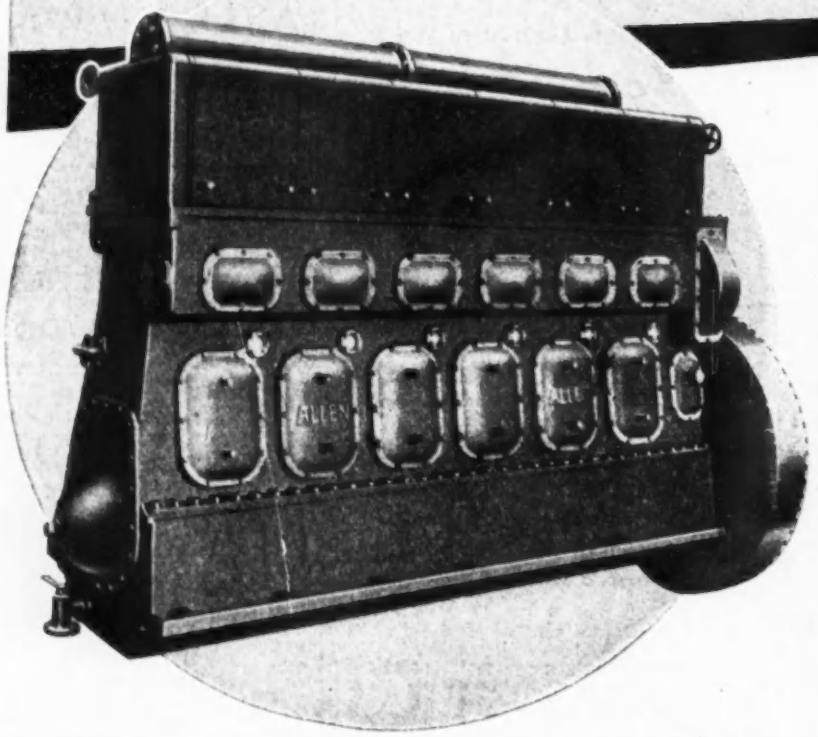
VISCO
AIR FILTERS
DUST COLLECTORS
COOLING TOWERS 8384
THE VISCO ENGINEERING CO., LTD.,
Stafford Road, Croydon. Phone: Croydon 4181/4

ELEVATORS
BARRY, HENRY & COOK, LTD.
789

Wanted, Portable Steam ENGINES, all sizes, ALSO GARRETT LOCOMOBILE SETS.—FRED WATKINS, Coleford, Glos. J 758

SLUICING 9796
STREET, LONDON, E.C.4





Among the range of Allen engines is the S37-B medium speed type which is designed and constructed for continuous service requirements in power stations, industrial works, pumping stations, and other fields of application. Illustrated above is an 8-cylinder engine and 420 kW. alternator, and on the left, a 6-cylinder, 480 b.h.p. engine. This type of engine runs at speeds up to 450 r.p.m. and covers powers from 200 to 640 b.h.p. in 3 to 8-cylinder sizes.

Alternative types of Allen engines are available from 30 to 1,200 b.h.p., and units can be supplied with generators, pumps and equipment of our own construction for complete power generating and pumping installations.

The repeat orders which we continue to receive from users in many different industries and public services, testify to the high standard of operating efficiency and reliability of Allen installations in all parts of the world.

966

W. H. ALLEN, SONS & Co. LTD.

TELEGRAMS
PUMP, BEDFORD
PUMP, SOWEST, LONDON

BEDFORD, ENGLAND.
LONDON OFFICE: 5 VICTORIA STREET, WESTMINSTER, S.W.1.

TELEPHONES
BEDFORD 2201
ABBEY 2712

TEMPERATURE OF FLAME GASES.

By PROFESSOR W. T. DAVID, Sc.D., M.Inst.C.E.

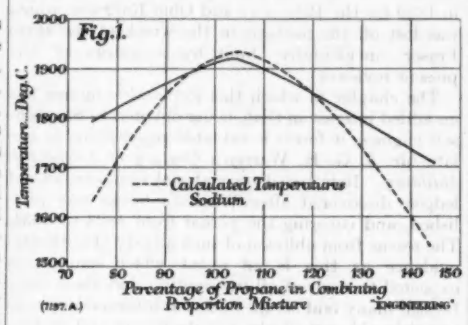
A KNOWLEDGE of the temperature of flame gases is usually necessary in connection with heat-transfer problems in various technical processes. Many believe that the sodium-line reversal method is the most reliable way of determining these temperatures,*† but the flame-gas temperatures so determined may be, and generally are, much too high, often some hundreds of degrees too high, even when the measurements are postponed until the flame gases have entirely emerged from the combustion zone. The reasons for this would appear to be as follows:—(i) The inflammable gaseous mixtures before combustion are never, either in industrial practice, or, indeed, in the large number of laboratory experiments which have been made, of homogeneous composition, and (ii) the CO_2 and H_2O molecules in the flame gases after combustion are in an excited state and may communicate their excess energy to the sodium atoms. We will discuss first the influence of lack of homogeneity in the inflammable gaseous mixtures.

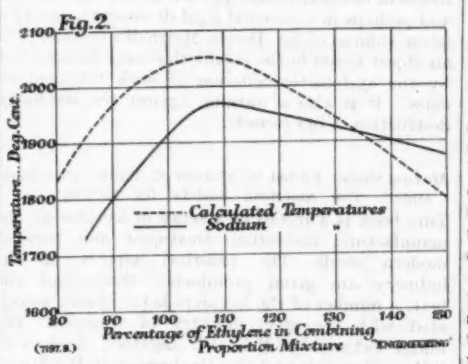
Most of the sodium temperature determinations have been made just above the inner cone in the flame gases in Bunsen or Meker burner flames. Some typical examples are shown in Figs. 1 and 2. The measurements were made by Jones, Lewis, Friauf and Perrott,‡ the inflammable mixtures supplied to the burners being mixtures of various strengths of propane and air (Fig. 1) and ethylene and air (Fig. 2). The ideal temperatures calculated upon the basis of spectroscopic specific heats and dissociation constants are also shown in the diagrams. It will be seen that the sodium temperatures bear no very obvious relationship to the calculated temperatures. A better correlation obtains in the ethylene flames than in the propane flames, but in both cases the sodium temperatures are greater than the calculated temperatures when the inflammable mixtures supplied to the burners are very over-rich. It was pointed out by Bauer§ that this may be due to the flame gases being totally coloured by sodium vapour, for, although the focusing was in the axis of the flame just above the inner cone, the higher temperature in the surrounding flame gases, owing to secondary combustion, may contribute; and this has been shown to be the case by Kaveler and Lewis. It is, however, by no means the entire explanation, for the experiments of Minkowski, Müller and Weber-Schäver show that even when steps are taken to colour the central portion only of the flame gases, sodium temperatures nearly 200 deg. C. higher than the calculated may still be obtained in very over-rich mixtures. When weak mixtures are fed to the burner no secondary combustion can take place, and, therefore, no contribution from this cause can have affected the high weak mixture ethylene temperatures. Indeed, Kaveler and Lewis measured temperatures higher than the calculated in centrally-coloured flame gases resulting from the combustion of weak Pittsburgh natural gas-oxygen mixtures.

In view of the centrally-coloured flame results, it appears to be generally assumed that temperatures higher than the calculated may obtain in flames, and, indeed, Lewis and von Elbe (*loc. cit.*) have introduced the theory of excitation lag to account for them. It appears to me, however, that the excessive temperatures in weak and over-rich mixtures are due simply to the fact that the combustible gas and air mixtures during their travel up the burner tube do not mix intimately; indeed, they are in a stratified condition at the time they reach the inner combustion cone. It will be clear, therefore, that when the mixture fed to the burner is either weak or over-rich there will be small portions of considerably higher calorific value than that averaged over the whole mixture, and these small portions after combustion will have a higher temperature than the average flame temperature. In view of the very rapid increase in the intensity of the sodium D-lines with temperature, these small high-temperature portions will have a great, perhaps a dominating, influence upon the flame-gas temperatures as determined by the sodium method.

In the light of the suggestion of the influence of imperfect mixing of the inflammable gas-air mixtures fed to the flame upon the measured sodium flame gas temperatures, it would appear that, for some reason or other, Jones, Lewis and Seaman had secured better mixing in their ethylene experiments (Fig. 2) than in their propane experiments (Fig. 1). Even so, the mixing in the ethylene experiments seems to have been far from perfect, for, although the sodium temperatures in the weak ethylene mixture flames bear a reasonable relationship to the calculated temperature, they are still above the calculated temperatures for very over-rich mixtures.

Jones, Lewis and Seaman* made some interesting sodium measurements in flame gases resulting from





the combustion of methane-air mixtures in which small quantities of air were replaced by equivalent amounts of oxygen. Their results are given in Table I for mixtures containing 9 per cent. of

TABLE I.

Mixture.	Sodium Flame-Gas Temperatures.
9 per cent. CH_4 + 91 per cent. air ..	1,820 deg. C.
9 per cent. CH_4 + 1 per cent. O_2 + 90 per cent. air	1,830 deg. C.
9 per cent. CH_4 + 2 per cent. O_2 + 89 per cent. air	1,870 deg. C.
9 per cent. CH_4 + 3 per cent. O_2 + 88 per cent. air	1,935 deg. C.

methane. The mixtures are all on the weak side of the combining proportions mixture (9·47 per cent. methane with atmospheric air), and there seems to be no apparent reason why the flame temperatures should vary appreciably with oxygen replacements. Indeed, David and Jordan† found inappreciable variation in the flame temperatures of these mixtures as recorded by fine platinum wires during the pre-pressure period in large closed-vessel explosions. As will have been seen from Table I, however, the sodium-flame temperatures increase greatly with oxygen replacement, and the 2 per cent. and 3 per cent. oxygen mixtures yield sodium temperatures which are higher than the calculated. It was at one time thought that these sodium temperatures were of fundamental significance, and Lewis and von Elbe (*loc. cit.*) regarded them as giving further support to the excitation lag theory. They may, however, be readily explained in terms of imperfect mixing, for any small portions of mixture containing more than 9·47 per cent. of methane will have a higher calorific value the greater the oxygen replacement.

It would seem clear, therefore, that, in the case of weak and over-rich mixtures, the sodium method cannot be expected to give a reliable indication of the (mean) temperature of the flame gases resulting from their combustion, unless, as is practically never the case in practice, the mixtures are perfectly mixed before combustion. In the case of slightly rich mixtures which after combustion yield the maximum flame-gas temperatures, it will be obvious that the effect of imperfect mixing will be small and the sodium temperatures which have been measured for such mixtures may be taken as being sensibly the same as those which would have been measured by the sodium method for perfectly homogeneous mixtures. It will be of interest, therefore, to compare the maximum sodium temperatures for various combustible gas-air mixtures with those determined by other methods. Ribaud, Laure and Gaudry, who are advocates of the sodium method, have compiled a table of what they regard to be the most trustworthy maximum temperatures for various combustible gas-air mixtures determined by the sodium method and by the thermo-electric method. The temperatures shown in Table II have been selected mainly from their

TABLE II.

Combustible Gas.	Sodium Flame Temperatures.	Thermo-Electric Flame Temperatures.
Hydrogen	2,045 deg. C.	1,800 deg. C.
Ethylene	1,970 deg. C.	1,800 deg. C.
Acetylene	2,325 deg. C.	2,120 deg. C.

table. The sodium temperatures were determined by Jones, Lewis and Seaman, and the thermo-electric results by Passauer,* who used thermo-couples of decreasing diameter and extrapolated the resulting graph to zero diameter, thus making allowance for radiation loss from the thermocouple.

It will be seen that the maximum flame-gas temperatures determined by the sodium method are some 200 deg. C. greater than those determined by the thermocouple method. This is much in line with the view put forward by the writer some time ago in ENGINEERING,† but against this has to be set the fact that experimenters who have measured sodium and (electrically-heated) platinum-wire temperatures in the same flame gases found very similar temperatures by both methods. Thus Griffiths and Awbery,‡ who were the last experimenters to make this comparison, found for flame gases from a certain unspecified mixture a temperature of 1,883 deg. C. by the sodium method and 1,886 deg. C. by an electrically-heated rhodium wire of 0·2 mm. diameter. Griffiths and Awbery's sodium temperatures for CO-air flames are, however, the lowest on record (by nearly 150 deg. C.), and this may possibly be the reason why they found agreement between their sodium and wire temperatures. Whatever the explanation, however, it seems difficult to disregard entirely the experimental results shown in Table II.

It is suggested that both the sodium temperatures and the wire temperatures are greater than those corresponding to the mean molecular translational energy in the flame gases—the former to a greater extent, the latter to a less extent. It is, I think, definitely established that there exists in flame gases excited CO_2 and H_2O molecules holding an excess of intra-molecular energy over and above that held by normal CO_2 and H_2O molecules under corresponding conditions, and this excess intra-molecular

* Ribaud, Laure and Gaudry, Symposium on Gas Temperature Measurement, *Journal Institute of Fuel*, March (Special Issue), 1939.

† Lewis and von Elbe, "Combustion Flames and Explosions of Gases," Cambridge University Press, 1938.

‡ Jones, Lewis, Friauf and Perrott, *Journal American Chemical Society*, vol. 53, page 869 (1931).

§ Bauer, *Ann. de Chim. et Phys.*, vol. 29, page 244 (1913).

* Jones, Lewis and Seaman, *Journal American Chemical Society*, vol. liii, No. 3, page 3993 (1931).

† David and Jordan, *Philosophical Magazine*, vol. xviii, page 228 (1934).

* Passauer, *Gas and Wasserf*, April 5, 1930.

† David, ENGINEERING, vol. 138, page 475 (1934).

‡ Griffiths and Awbery, *Proc. Roy. Soc.*, A, vol. 123, page 401 (1929).

energy may be communicated to the sodium atoms during collision and to the wire when they strike it. Some experiments by Kohn* are of much interest in this connection. He showed that when an electrically-heated platinum wire was placed in flame gases, the temperature measured by the sodium method at a point in the flame gases just above the wire was less when the wire was present than when it was removed. The explanation would appear to be that the hot wire normalised the excited CO_2 and H_2O molecules, which then had no excess of intra-molecular energy to communicate to the sodium atoms.

This discussion suggests that some form of the wire method (resistance or thermocouple) is preferable to the sodium method for the measurement of the temperature of flame gases, and particularly is this the case when the inflammable mixtures before combustion are imperfectly mixed. Experiments are now proceeding with quartz-covered platinum wires, and it is hoped to discuss these in a subsequent article.

LITERATURE.

Factory Layout Planning and Progress. By W. J. Hiscox. London: Sir Isaac Pitman and Sons, Limited. [Price 7*s.* 6*d.*]

With each year that passes, the proper planning of factories becomes of more and more importance. Competition becomes increasingly keener as better articles are made at less cost, so that, unless the producing unit is efficient and the processes are carried out economically, the full measure of success cannot be achieved. For this reason, therefore, Mr. Hiscox's book may be welcomed, the more so as it is helpful in conception and reflects an orderly and experienced mind. The book is conveniently divided into two parts, covering, respectively, Planning and Routing, and Progress Work. In the first part, the author deals with the all-important question of which individual items, making up a composite article, should be made at the works, and which should be purchased outside. Such problems become particularly significant when special processes are involved.

As the title specifically includes the word "factory," it might be expected that the book would deal with industries generally; but, except for passing references, no mention is made of industries other than engineering. A better title would have been "Engineering Works Planning and Progress," as this would describe more accurately its main contents. The problems in planning which confront, say, the biscuit maker, uncertain whether or not to install equipment for the production of metal boxes and paper cartons, or a large-scale motor-car manufacturer who has to decide whether his primary raw materials should be metals or their ores, are beyond the scope of the book.

The author does deal, however, in a very thorough manner with the problems encountered in an engineering works, in the planning of the manufacturing departments for continuous or batch production, the location of departments, and the allotment of duties of the executive staff. He rightly stresses the fact that production planning, to be effective, must commence with the design. The ideas of the designer and the works planner must be reconciled in order to permit economic manufacture.

Early British Locomotives. By C. F. Dendy Marshall, M.A. London: The Locomotive Publishing Company, Limited. [Price 10*s.* in paper covers or 12*s.* 6*d.* in cloth binding.]

Any work on locomotive history by Mr. Dendy Marshall is assured of an appreciative reception, not only from the many who are merely interested in the colourful story of the beginnings of rail locomotion, but also from the small but earnest band of those who know from experience how much labour can go to the determination of a single historical fact among the tangle of early railway legend. The author's *Two Essays in Early Locomotive History* have acquired the status of classics in this field, and it is sufficient commendation of the present volume that it is a continuation of the previous book.

It is not to be expected that a collection of supplementary notes can present anything approaching a connected narrative; and, particularly to those who are not familiar with the *Two Essays*, the book may appear somewhat disjointed. Inevitably, too, it leaves many "loose ends," requiring further research for their elucidation, but there can be no question that Mr. Dendy Marshall has taken the right course in placing on record the results thus far achieved, incomplete though they may be, to stimulate interest and perhaps to enlist additional aid in tracing the links which are still missing. A list of nine engines is given in the preface—among them the first locomotive in Scotland—further details of which would be welcomed if they could be brought to light. It may be surmised, however, that few who take up the search will outdo in thoroughness Mr. Dendy Marshall himself, who even employed a diver to explore the sea bed off Peterhead in the hope of discovering some trace of an engine built by Robert Stephenson and Company in 1829 for the Baltimore and Ohio Railroad, which was lost off the harbour in the wreck of the sloop Fraser (incidentally, built by ancestors of the present reviewer).

The chapter in which this locomotive figures has an added interest in that, being devoted to Stephenson engines, it forms a valuable supplement to the late Mr. J. G. H. Warren's *Century of Locomotive Building*. It is based on material found in an old ledger, discovered after Warren's books was published, and covering the period from 1823 to 1831. The rescue from oblivion of such a body of authentic evidence as this is an event which cannot be expected to recur at all frequently; but there must be still many odd scraps of useful information to be found in old periodicals, private letters and diaries, and perhaps in occasional legal documents, and this latest volume of Mr. Dendy Marshall's researches is an object lesson in the results that may be achieved by the systematic collation of such fragmentary clues. It is also a warning against the too-hasty destruction of old records.

Modern Steels. Edited by Ernest E. Thum. Cleveland, Ohio: The American Society for Metals.

This book is a record of a series of lectures on the manufacture, inspection, treatment and uses of modern steels. The practical aspects of the industry are given prominence throughout the text, a number of the lecturers being closely associated with the steel industry of America. The initial lecture, by Max. W. Lightner, deals with "Raw Materials and the Production of Pig Iron," and traces the history of the industry from its primitive stages to its present highly-developed state. The second lecture, by the same author, is a study of modern steel-making processes. The crucible process, formerly predominant in the production of fine grades of steel for tool manufacture, has been largely replaced in America by the electric furnace, which is more economical and produces a steel of equal quality. The electric furnace has become increasingly popular during the last few years, due to the demand for special alloy steels. Prof. G. R. Fitterer deals with "Steel Pouring," and "Testing of Steel," and surveys recent developments in the control variables in furnace technique, for the production of steel to meet difficult specifications. The outline given of steel tests describes, in general terms, some of the more common methods and the recently-adopted procedure for inspection purposes, but detailed information must be sought elsewhere.

The section on "Metallography," contributed by Franklin H. Allison, Junr., discusses the equilibrium structures of steel, and slowly-cooled, quenched and tempered steels. Developments during the last fifty years are systematically presented, but consideration is limited to the crystalline structure of metals, the structure of high-purity iron, thermal critical points, the thermal equilibrium diagram of carbon and iron, and the structures found in hardened and tempered steels. It is what happens to the iron carbide during processing which is of the utmost importance in the manufacture of articles from steel. A. W. Demmler reviews the fundamentals of annealing, spheroidising, normalising, hardening and tempering, quenching practice, and the trend towards the continuous type of furnace for annealing and hardening. The lectures on alloy, stainless and tool steels adequately cover a wide field, particular consideration being given to the effect of the alloying elements and the general characteristics which they impart. Although the book covers no ground unfamiliar to the specialist, there are many non-specialists requiring dependable technical data on steels and their uses in different branches of engineering activity, such as chemical engineering, for whom a work of this character possesses definite value.

A Romance of Industrial Engineering. By James A. Morris, F.R.S.E. Kilmarnock: Glenfield and Kennedy, Limited. [Price 15*s.* 6*d.*]

One of the most comforting reflections in an age of amalgamations, mergers, and astronomical industrial finance is that these tendencies of the time, however much they may overshadow manufacturing operations, can do little or nothing to suppress native initiative and ingenuity. It is idle to deny, however, that modern commercial conditions are making it increasingly difficult for individual inventors to establish a new engineering business, after the manner of the pioneers immortalised by Samuel Smiles; and there are likely to be progressively fewer historical records of engineering firms, comparable with this survey by the chairman of Messrs. Glenfield and Kennedy, Limited.

The story begins with the invention of the Kennedy water meter (although Mr. Morris gives a fuller measure by prefacing his main narrative with an interesting chapter on old Kilmarnock) and describes in detail the process of development from the original syndicate of Thomas Kennedy, a watchmaker and gunsmith, who was the patentee; Alexander J. Bruce, a banker; William Taylor, a carpet manufacturer; and Robert Blackwood, secretary of the Kilmarnock Water Company. Some uncertainty appears to surround the authorship of the initial idea of the meter, but it was patented by Kennedy in 1852, and the first meters were made by John Cameron, another gunsmith, who also developed the details of the mechanism. The syndicate, which had been operating as the Kennedy Patent Water Meter Company, transferred its interests, in 1865, to a new "Kennedy's Patent Water Meter Company, Limited." The Glenfield Company was formed in the same year for the purpose of supplying castings to the Kennedy Company, but, almost at once secured an important order for the supply of valves to a Belgian waterworks, thus laying the foundation of what has subsequently developed into an important section of their business. Eventually, in 1900, the two companies amalgamated to form the present firm of Glenfield and Kennedy, Limited.

This is the bald outline of the story, but conveys no impression of the care that has been taken to verify details and to support them by appropriate extracts from the minutes of the Board, personal recollections, maps and other documents, and biographical notes of directors and senior officials. The emphasis on the personalities of the men who have built up the business is strong throughout; indeed, the references to the firm's later achievements, in the field of heavy hydraulic engineering, are introduced almost incidentally. Doubtless, this was intentional; the book is a serious contribution to industrial history and not merely a catalogue of contracts duly completed and, for the most part, already fully described elsewhere. Its success is best measured, perhaps, by the feeling which it induces, that to have lived and worked with these men must have been a liberal education.

Softwood for Motor-Vehicle Construction.—We are informed that manufacturers or coach builders requiring imported softwood for the production of motor vehicles for civilian use in this country, must apply to the Ministry of Transport for a certificate of purchase. Applications should be made in triplicate, on form TC 3/8/1, which may be obtained from the Timber Control Area Officer, and forwarded to the Secretary, Ministry of Transport, Room 349, Metropole Buildings, Northumberland-avenue, London, W.C.2.

* Kohn, *Ann. Phys.*, vol. 44, page 749 (1914).

THE ENGINEERING OUTLOOK.

VII.—TEXTILE MACHINERY.

THE year 1939 saw an increase in the activity of the majority of textile-machinery manufacturers, though this was due for the most part to the receipt of further armament orders rather than to any improvement in demand for textile machinery. Several manufacturers did report some recovery in home demand, but export orders declined and, since export markets probably account for rather more than 90 per cent. of the total demand for textile machinery, this fall more than outweighed, for the majority of producers, any improvement which took place in the home market.

TABLE I.—*Net Imports of Textile Raw Materials* (000 *Tons*).

—	1932.	1933.	1934.	1935.	1936.	1937.	1938.	1939. (Jan.-Aug.)
Cotton ..	537	605	537	535	663	714	519	284
Wool ..	192	268	236	270	295	256	283	279
Silk (tons) ..	209	246	320	281	304	332	305	146
Flax ..	49	51	62	56	66	56	57	50
Hemp ..	62	64	86	85	89	98	79	61
Jute	130	148	173	152	166	170	160	116

As a result of the fairly high level of exports maintained in 1937 and 1938, Textile Machinery Makers, Limited, the amalgamation which took over the textile machinery interests of six of the leading manufacturers (Asa Lees and Company, Limited, Brooks and Doxey, Limited, Dobson and Barlow, Limited, Howard and Bullough, Limited, John Hetherington and Sons, Limited, and Platt Brothers and Company, Limited) paid a maiden dividend of 5 per cent. in respect of 1938. Even this distribution, however, owed something to armament orders and Sir Walter Preston, speaking in May, 1939, at the annual meeting of Platt Brothers and Company (Holdings), Limited, said, in respect of the financial year ended March 31, 1939, that, although a certain amount of the munitions work had been received during the year by the textile-machinery making subsidiaries, there was an appreciable falling-off in the volume of textile-machinery orders. He added that the state of the order book promised, with moderate certainty, a repetition of the dividend for the year to March 31, 1940.

Some of the textile-machinery makers outside the combine were able to report improved home demand during 1939, but for the most part these companies were engaged in the production of specialised types of machinery; for example, the report of the British Northrop Loom Company for the year ended October 21, 1939, stated that trade improved steadily throughout the year and that the plant was operated to capacity. Moreover, work in hand was sufficient to ensure full working for some time. This company had received an important order, valued at over 100,000*l.*, for the provision of looms for the new Egyptian cotton mill at Kafr el Dawar, near Alexandria.

In general, however, although there was some improvement in the home demand arising from the greater activity in the textile industry generally, particularly cotton and jute, the improvement was not so great as had been anticipated, owing to fears on the part of the Lancashire cotton industry that the Government were allowing consideration of the Cotton Bill to drag along so slowly that it might not pass before the end of the session, and, therefore, might be dropped or passed in a greatly weakened form.

Some indication of the probable trend of home demand for textile machinery can be obtained from movements in net imports of textile raw materials, which reflect the state of activity in the textile industry. It is not to be expected, of course, that the demand for textile machinery will follow closely the fluctuations in these imports, but whenever a steady expansion of activity occurs in any particular branch of the textile industry it is reasonable to expect that this will be reflected in increased orders for machinery. The figures for net imports of textile raw materials shown in Table I, herewith, are available only to August, 1939. On a monthly basis, net imports of raw cotton averaged 43,250 tons per month in 1938 and 35,500 tons in the first eight months of 1939; of wool, 23,600 tons in 1938 and 34,900 tons in 1939; of silk, 25·4 tons in 1938 and 18·2 tons in 1939; of flax, 4,750 tons in 1938 and 6,250 tons in 1939; of hemp, 6,600 tons in 1938 and 7,600 tons in 1939; and of jute, 13,300 tons in 1938 and 14,500 tons in 1939.

There is reason to believe, however, that in the case of cotton and wool, and possibly to a lesser extent in that of other fibres, there were considerable changes in the stock position during 1939. In the cotton industry, for example, there was almost certainly some improvement in activity in the early months of 1939, and stocks of raw cotton in this country were considerably reduced. The decline in imports of raw cotton was largely due to the artificial restriction of supplies of American cotton, through the granting of loans to growers and the subsequent controversy. This dispute did not end until July 27, when it was announced that a subsidy of 1½ cents per pound would be paid on exports of American cotton. As a result of this, stocks of American cotton in this country were abnormally low at the outbreak of war. The possibility of stock changes of this order must be borne in mind when considering the figures in Table I, but such changes are normally made good at a comparatively early date, so that, over a period of years, the figures may be taken to indicate fairly satisfactorily the trend of activity in the various branches of the textile industry.

TABLE II.—*Textile Machinery: United Kingdom Retained Imports.*

Monthly Average.	Volume.	Index. (1913 = 100.)	Value. £ per Ton.	Index. (1913 = 100.)
1913	411	100	71·6	100
1932—				
1st Qr. ..	1,130	274·9	131·0	183·0
2nd ,, ..	531	129·2	133·7	186·7
3rd ,, ..	323	78·6	159·0	222·1
4th ,, ..	559	136·0	142·4	198·9
1933—				
1st Qr. ..	262	63·7	209·9	293·2
2nd ,, ..	218	53·0	210·8	294·4
3rd ,, ..	341	83·0	201·8	281·8
4th ,, ..	345	83·9	179·5	250·7
1934—				
1st Qr. ..	347	84·4	225·3	314·7
2nd ,, ..	494	120·1	173·8	242·8
3rd ,, ..	439	106·9	186·7	280·7
4th ,, ..	423	103·9	202·1	276·6
1935—				
1st Qr. ..	559	136·4	189·5	264·5
2nd ,, ..	649	158·1	158·5	221·1
3rd ,, ..	512	124·6	197·5	275·8
4th ,, ..	606	147·5	218·0	302·4
1936—				
1st Qr. ..	476	116·0	240·0	334·8
2nd ,, ..	757	186·5	204·5	287·0
3rd ,, ..	551	134·1	190·0	268·0
4th ,, ..	498	121·4	184·3	260·0
1937—				
1st Qr. ..	443	107·8	186·8	246·9
2nd ,, ..	517	125·8	127·0	177·4
3rd ,, ..	610	148·4	223·2	312·0
4th ,, ..	413	100·5	205·7	287·3
1938—				
1st Qr. ..	320	77·8	218·7	305·5
2nd ,, ..	399	97·0	183·7	256·5
3rd ,, ..	360	87·6	179·7	251·0
4th ,, ..	414	100·7	299·3	406·5
1939—				
1st Qr. ..	465	108·9	227·4	319·4
2nd ,, ..	550	136·2	225·9	303·9
3rd ,, ..	567	138·0	227·8	319·8

In the first eight months of 1939, gross imports of textile machinery rose to 4,178 tons, valued at 954,661*l.*, from 2,865 tons, valued at 646,430*l.*, in the corresponding period of 1938. The increase was spread over all categories, but was particularly pronounced in the case of machinery for spinning and twisting (including all preparatory processes) and of hosiery and knitting machinery. The rise in the latter category suggests that the German decision to restrict exports of certain machinery for the manufacture of full-fashioned hose, which was taken in 1938 in order to strengthen the hold of German textile manufacturers on the world market for the highest class of hosiery, did not prevent British firms from obtaining the machinery they required; though, in the absence of more detailed statistics regarding the types of machinery imported and the countries of origin, this cannot be stated definitely. British hosiery exports as a whole, however, increased in 1939. Re-exports of textile machinery totalled 107 tons, valued at 42,433*l.*, in the first eight months of 1939, compared with 138 tons, valued at 60,267*l.*, in the corresponding period of 1938. Net imports on a quarterly basis are shown in Table II, on this page, from which it will be seen that there was a steady increase throughout the year.

As already mentioned, British exports of textile machinery in 1939 showed a considerable fall compared with the previous year, totalling 35,758 tons, valued at 4,583,000*l.*, in the first eight months of 1939, against 50,712 tons, valued at 5,963,000*l.* As shown in Table III, above, practically the whole of the decline took place in exports of machinery for spinning and twisting, including preparatory processes, which fell from 35,949 tons in the period January to August, 1938, to 21,191 tons in the corresponding period of 1939. Exports of machinery for processes preparatory to weaving but subsequent to spinning and twisting also declined, but these are always relatively small. On the other hand, exports of looms and parts rose from 8,862 tons to 9,128 tons, and those of other types of machinery were well maintained. These changes in the export demand for the various types of machinery are for the most part the direct opposite of those which were experienced in the previous year, when exports of spinning and twisting machinery increased while those of looms fell. They are, probably, largely responsible for the fact noted at the beginning of this article, that, while most firms reported a fall in orders in 1938, a few experienced greater activity than in the previous year.

Quarterly exports of textile machinery are shown in Table IV, opposite, from which it will be seen that there was a steady decline in exports from the fourth quarter of 1937 until the second quarter of 1939, but there was a very slight recovery in the third quarter of last year. Although the average value per ton declined in the first quarter of 1939, this was followed by a further increase to the record figure of 133·1*l.* per ton in the second quarter. Average value per ton, of course, does not

TABLE III.—UNITED KINGDOM: EXPORTS OF TEXTILE MACHINERY BY CLASSES.

	Tons.			£000's.			Tons.		£000's.	
	1936.	1937.	1938.	1936.	1937.	1938.	1938. (Jan.-Aug.)	1939. (Jan.-Aug.)	1938. (Jan.-Aug.)	1939. (Jan.-Aug.)
For spinning and twisting, including all preparatory processes	33,479	46,849	40,003	3,700	5,248	5,672	35,949	21,191	4,108	2,845
For processes preparatory to weaving but subsequent to spinning and twisting	1,751	897	1,040	147	98	103	829	419	82	48
Looms and parts (excluding bobbins)	10,557	15,387	12,671	917	1,295	1,176	8,862	9,128	820	793
Printing and finishing	1,940	3,532	4,067	188	296	418	2,332	2,341	225	243
Hosiery and knitting	698	839	559	443	538	467	366	425	309	330
Parts (bobbins)	1,544	1,590	1,558	208	267	294	1,037	1,019	212	149
All other sorts	3,221	3,171	2,087	356	369	296	1,337	1,235	207	174
Total	53,190	72,265	70,985	5,959	8,111	8,427	50,712	35,758	5,963	4,583

necessarily represent a true index of prices, since technical progress is largely expressed through reductions in weight resulting from the use of stronger and lighter alloy materials. Nevertheless, the increase in average value per ton can hardly be accounted for entirely on the grounds of improved methods of construction or of increased complexity of the product. Figures for average value per ton subsequent to the third quarter of 1939 are likely to show a further sharp advance, since manufacturers of textile machinery decided in September, 1939, to advance prices by 20 per cent. to 25 per cent. This decision was taken owing to increased costs of production and higher prices of materials.

In the first eight months of 1939 the principal market for British exports of textile machinery was again India, which took 13,091 tons, against 20,726 tons in the corresponding period of 1938. India thus accounted for about 37 per cent. of the total exports; no other single country took more than 3,000 tons. The second largest market in 1939 was Egypt, which took 2,692 tons, against 1,145 in 1938. Germany was the third largest market, though the steady increase in exports to this country, which was noted over the three years up to 1938, was not continued last year. In the first eight months of 1939, exports to Germany totalled 2,051 tons, compared with 3,334 tons in the corresponding period of 1938.

In former years, the Soviet Union was an important market for British textile machinery, but recently production in that country has been developed to the point where it supplies the bulk of the home demand, together with a small surplus in some types of machinery for export to neighbouring countries. Nevertheless, it was hoped about the middle of the past year that, as a result of the visit of the Secretary for Overseas Trade to Russia, that country would place orders in Lancashire for some of the machinery necessary to equip the new cotton mills which were about to be erected. Subsequent political developments, of course, have prevented the placing of any substantial orders. During 1939 a claim to have made a revolutionary development in weaving was made in Russia. This was the production of a new type of loom in which the necessity for a shuttle to carry the bobbin was said to be completely obviated. The first looms of this type are being installed at the Sobokvo-Shchelkovo spinning and weaving mill, near Moscow. Advantages claimed for this loom are that it is much simpler in construction than the standard type, as the elimination of the shuttle renders unnecessary a number of auxiliary parts, the bobbin can be changed while the machine is in motion, and stoppages through the breaking of warp and weft are said to be prevented, while provision is made for automatic stopping if anything is wrong. Under normal conditions, it is claimed, the loom will run continuously for three or four days.

South American countries are not, for the most part, large importers of textile machinery, though British exports to Brazil amounted to 1,839 tons in the first eight months of 1939, and to the Argentine, 828 tons. In addition, Germany has an important export trade to South American countries, notably to Brazil. In 1939, it was announced that Chile might shortly be in the market for increased quantities of textile machinery as a result of the earthquake in South Chile. This caused a good deal of damage in the textile industry, which is largely concentrated in the Concepcion district. Although it was considered that much of the damaged machinery could be repaired or reconstructed in the country, a fair proportion, particularly of looms, was completely destroyed. A case was presented, therefore, for allowing the importation of looms for replacement free of duty.

In Peru, on the other hand, imports of textile machinery have been prohibited, except in certain special cases approved by the Ministries of Finance and Public Works. The law was first passed in June, 1938, for a period of twelve months, and in 1939 it was extended for a further two years. It was stated that the textile machinery already installed in the country was sufficient to cover domestic requirements, and that further imports would bring about an over-production of textiles.

The United States is another market which formerly took appreciable quantities of British textile machinery, but in the first eight months of 1939 it took only 857 tons. In his speech in May, 1939, previously mentioned, Sir Walter Preston stated that the lowering of the United States tariffs had already had such results that one of his colleagues had gone out there to attempt to revive a market which had been regarded as lost. Early in 1939, it was announced that Mather and Platt, Limited, had reached an agreement for technical co-operation with an important United States producer of machinery for dyeing and finishing rayon fabrics, with a view to incorporating certain special features in their own production. The company also announced that they had received an important contract for the equipment of a complete works in the Philippine Islands, a market which had formerly been regarded as a monopoly of the United States.

Tables V and VI, on this page, show international exports of textile machinery by volume and value, respectively. It will be seen that, while there was a general contraction in export trade from all countries, British exports fell rather more heavily than those from other countries, with the result that the British share of total exports by volume fell from 41·7 per cent. of the total in 1938 from the countries shown in Table V to 38·6 per cent. in the first eight months of 1939; and by value, from 42·9 per cent. of the countries shown in Table VI to 33·9 per cent. This was due mainly to an improvement in the relative position of Germany, German exports by volume increasing from 21·4 per cent. of the total to 26·2 per cent. There was, nevertheless, a very sharp rise in the average value per ton of German exports, from 157*l.* in 1938 to 195*l.* in 1939; an increase which was even greater than that which took place in the case of British exports. While this may have been due partly to changes in the types of machinery exported, probably it also indicates some lessening of the export subsidies paid by the German Government.

In April, 1939, it was announced that eight important German engineering works, namely, Jean Güsken, Carl Zangs A.G., S. Lentz, Gruschwitz A.G., M. Rudolf Jahr, Joh. Kleinewefen Söhne, Rossweiner Machinenfabrik A.G., and Friedrich Hass, had amalgamated into the Vereinigung Deutscher Textilmaschinen Fabriken "Combitex." The main purpose of the amalgamation was to push German exports of textile machinery, and a joint selling organisation was created for this purpose at Cologne. The constituent companies adopted a measure of specialisation on particular types of machinery in order to increase output and lower production costs. In view of the range of machinery covered, the combine decided to undertake the planning and delivery of complete textile mills or of complete plants for the whole process of manufacture and finishing of fabrics.

The Japanese share of total exports, which had been increasing steadily from 5·4 per cent. in 1932 to 23·9 per cent. in 1938, showed a decline for the first time in 1939, to 21·1 per cent. Here again there was a considerable increase in the average value per ton, from 44*l.* in 1938 to 57*l.* in 1939.

TABLE IV.—*Textile Machinery: United Kingdom Exports.*

Monthly Average.	Volume.	Index. (1913 = 100.)	Value. £ per Ton.	Index. (1913 = 100.)
	Tons.			
1913	14,840	100	46·5	100
1932—				
1st Qr. ..	5,472	36·9	87·2	187·5
2nd ,, ..	5,666	38·2	86·3	185·6
3rd ,, ..	4,796	32·3	89·0	191·4
4th ,, ..	5,089	34·3	87·0	187·1
1933—				
1st Qr. ..	4,492	30·3	95·3	204·9
2nd ,, ..	4,514	30·4	95·2	204·7
3rd ,, ..	4,193	28·3	95·5	205·6
4th ,, ..	5,605	37·8	83·3	179·1
1934—				
1st Qr. ..	6,876	46·3	76·1	163·6
2nd ,, ..	6,780	45·7	85·8	184·5
3rd ,, ..	5,884	39·6	89·6	192·7
4th ,, ..	6,622	44·6	89·4	192·3
1935—				
1st Qr. ..	5,821	39·2	101·6	218·5
2nd ,, ..	5,703	38·4	102·2	220·0
3rd ,, ..	5,303	35·7	101·9	219·0
4th ,, ..	5,497	37·0	106·0	228·0
1936—				
1st Qr. ..	4,686	31·6	109·1	234·8
2nd ,, ..	4,057	27·3	118·0	254·0
3rd ,, ..	4,387	29·6	110·0	236·5
4th ,, ..	4,612	31·0	111·7	240·0
1937—				
1st Qr. ..	4,668	31·5	117·1	251·8
2nd ,, ..	5,538	37·3	114·7	246·7
3rd ,, ..	6,303	42·5	113·6	244·3
4th ,, ..	7,567	51·0	106·9	229·9
1938—				
1st Qr. ..	7,451	50·2	109·8	235·6
2nd ,, ..	5,867	39·5	120·7	259·4
3rd ,, ..	5,222	35·1	121·4	261·0
4th ,, ..	5,022	33·8	127·3	273·7
1939—				
1st Qr. ..	4,765	32·0	122·1	262·1
2nd ,, ..	4,274	28·8	133·1	282·5
3rd ,, ..	4,321	29·2	130·7	281·2

TABLE V.—INTERNATIONAL EXPORTS OF TEXTILE MACHINERY (VOLUME TONS).

—	1933.		1934.		1935.		1936.		1937.		1938.		1939.*	
	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.
United Kingdom ..	56,414	50·0	78,486	53·2	67,115	47·5	53,190	37·0	72,265	40·1	70,985	41·7	35,758	38·6
Germany	31,875	28·2	34,990	23·7	35,380	25·0	44,543	31·0	46,980	26·0	36,410	21·4	24,358	26·2
France	10,607	9·4	11,175	7·6	10,774	7·6	12,571	8·7	10,814	6·0	10,345	6·1	6,153	6·6
Switzerland	6,710	5·9	10,683	7·2	10,544	7·4	10,444	7·3	13,341	7·4	11,796	6·9	6,928	7·5
Japan	7,312	6·5	12,182	8·3	17,644	12·5	23,187	16·0	36,919	20·5	40,516	23·9	19,557	21·1
Total	112,918	100·0	147,516	100·0	141,457	100·0	143,935	100·0	180,319	100·0	170,052	100·0	92,754	100·0

* January to August.

TABLE VI.—INTERNATIONAL EXPORTS OF TEXTILE MACHINERY (£000's.)

—	1933.		1934.		1935.		1936.		1937.		1938.		1939.*	
	£000's.	Per cent.	£000's.	Per cent.	£000's.	Per cent.	£000's.	Per cent.	£000's.	Per cent.	£000's.	Per cent.	£000's.	Per cent.
United Kingdom ..	5,178	37·6	6,672	39·0	6,914	38·7	5,959	33·4	8,111	37·8	8,427	42·9	4,583	33·9
Germany	5,238	38·0	6,020	35·2	6,325	35·4	6,774	37·7	7,358	34·3	5,725	29·2	4,743	35·1
United States	1,170	8·5	1,445	8·4	1,702	9·5	2,118	11·6	2,217	10·3	1,542	7·9	1,213	9·0
France	841	6·1	876	5·1	804	4·5	768	4·3	584	2·7	514	2·6	390	2·9
Switzerland	1,042	7·6	1,602	9·4	1,397	7·8	1,417	7·9	1,671	7·8	1,622	8·3	1,463	10·8
Japan	297	2·2	496	2·9	737	4·1	882	4·9	1,519	7·1	1,782	9·1	1,113	8·3
Total	13,766	100·0	17,111	100·0	17,879	100·0	17,918	100·0	21,460	100·0	19,612	100·0	13,505	100·0

* January to August.

TRAILER FIRE PUMP.

MESSRS. THE HARLAND ENGINEERING COMPANY, LIMITED, ALLOA.

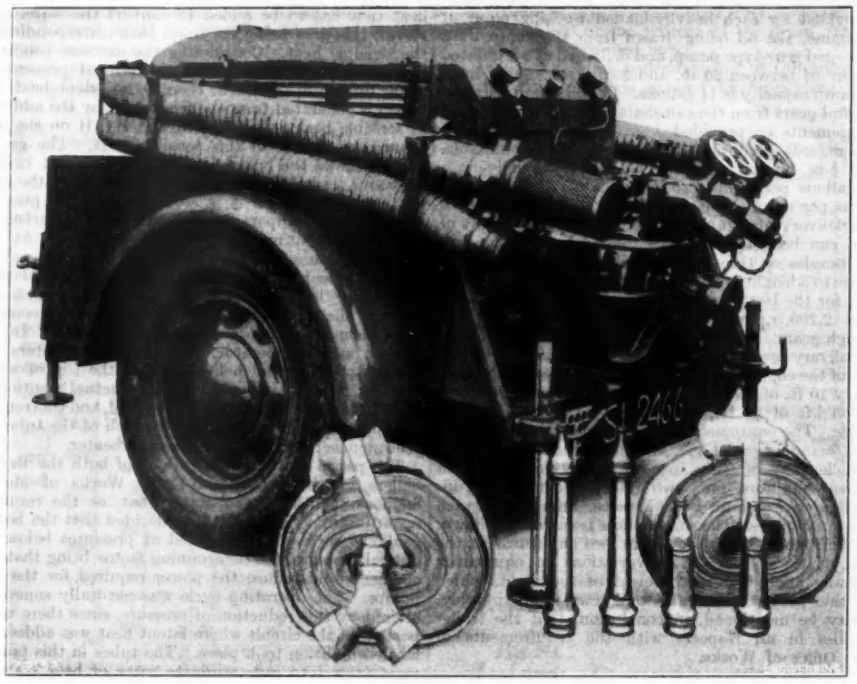


FIG. 1. TRAILER PUMP AND EQUIPMENT.

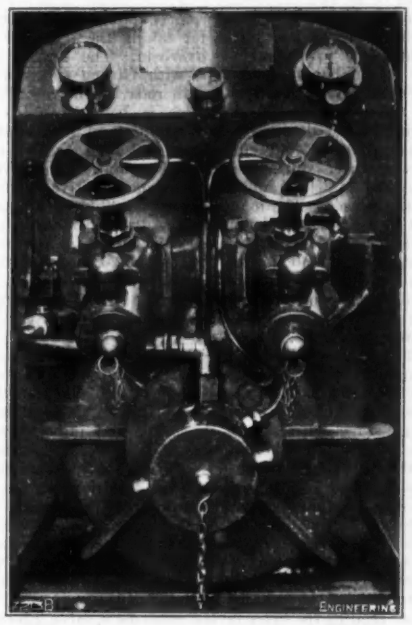


FIG. 2. PUMP CONTROLS.

It would seem that, in the immediate future, British textile-machinery makers are likely to become increasingly dependent on armament orders. That such orders have already reached considerable dimensions is shown by the statement of Sir George Bullough, chairman of Howard and Bullough (Securities), Limited, in June, 1939, that a large order had recently been obtained for aircraft parts. He added that this would enable one branch of the works, which had been closed for some time, to be re-opened. Since the outbreak of war, the demand for textile machinery, both from home and overseas sources, has been small and, though there are reasons for expecting some increase in home demand, export prospects are very uncertain. It is true that the elimination of German competition in overseas markets, notably India and South America, should improve the prospects of British manufacturers in those countries; but, on the other hand, a higher proportion of German exports of textile machinery normally goes to European countries contiguous to Germany than is the case with most other engineering products. Moreover, past experience, particularly in this country, has shown that it is possible to defer replacement and re-equipment for a long time, though whether this can be done without serious detriment to the efficiency of the textile industry is another matter. In view of the all-round increase in prices, it is very probable that textile firms abroad will tend to defer replacement during the war. Some countries, however, which are now dependent on imports for the whole or part of their textile supplies, may consider that it is in their interest to reduce this dependence by starting their own textile industry or increasing the existing capacity. In this they would be encouraged by the expectation that both Great Britain and Japan, the principal textile-exporting countries, might experience difficulty in maintaining exports.

In the home market, it is hoped that the revival in the demand for cotton goods will stimulate the demand for new machinery from the cotton industry. As already indicated, throughout 1939 the position as regards home demand for such machinery was overshadowed by uncertainty regarding the ultimate fate of the Cotton Industry (Reorganisation) Act. In some quarters it was estimated that, once the Act was passed, the cotton industry was likely to place orders for new machinery up to 1,000,000*l*. Actually, however, owing to the uncertainty of the position, many textile manufacturers tended to withhold orders which would otherwise have been placed, and, of the orders received by textile-machinery manufacturers, several were conditional on the Act being passed. This state of uncertainty prevailed practically until the outbreak of war, and manufacturers were then faced with the problem of adjusting themselves to an entirely new set of conditions, created by the imposition of war-time control.

For some years the surplus capacity of the cotton industry has been such that no improvement in activity was likely to be sufficient to compel the purchase of new machinery, and demand has been influenced rather by the level of profits earned, which, in turn, has regulated the amounts which individual firms have felt themselves able to devote to depreciation and replacement. A summary of the average dividends paid by cotton firms in 1939 (which relate mainly to activity during 1938 and the early part of 1939) shows that the average dividend of 121 spinning mills in that year was 5·43 per cent., against 5·66 per cent. in 1938. Of 71 spinning companies where a strict comparison is possible, 56 made profits in 1939, totalling 424,586*l*., and 15 announced losses, totalling 52,945*l*. In 1938, of the same 71 companies, 68 made profits, totalling 812,006*l*., while only three showed losses, aggregating 5,649*l*. It is clear, therefore, that, up to the end of 1939, the profit-earning capacity of the industry had not reached a point at which large-scale re-equipment was likely to be undertaken. The outbreak of war created a greater financial interest in cotton-manufacturing companies, and this may be the prelude to a period when finance for re-equipment may become more readily obtainable. On the other hand, of course, the risks inherent in war are restricting the amount of capital available for industry generally. In the event, much is likely to depend on the margin of profit allowed under the control on the increased business obtained.

One of the first results of the passing of the Reorganisation Act was the institution of a scheme for scrapping 60,000 redundant looms, at an estimated cost of 700,000*l*. The final scheme followed much the same lines as that which has been in force for the last few years in the spinning section of the industry. The necessary funds are to be raised by means of a levy at an average rate of 4*s*. per loom per annum.

In the wool industry, a high level of activity is likely to be maintained as a result of the heavy demand for uniforms and other woollen garments for the Services. In view of the fact that every effort is to be made to maintain and, if possible, expand exports, it is clear that the industry may have some difficulty in meeting the full demand. The prospects of an increased demand for machinery from the wool industry, therefore, are better than they have been for some time. The demand for sandbags has considerably increased activity in the jute industry, which had been running at a low level for some years, and this, again, may give rise to an increased demand for textile machinery. In the linen industry, however, difficulties in ensuring adequate supplies of flax may cause some decline in activity. It has been stated officially by a spokesman of the Ministry of Supply that special efforts are being made to increase the home and Empire production of flax.

In the rayon industry, the price-stabilisation pact was the first step towards a recovery from the price cutting which became intense as a result of the decline in demand in 1938. Since the outbreak of war, producers have been working at a high level of activity, which appears likely to continue as long as it is not necessary to restrict raw-material supplies. The industry now appears to be largely restored, as regards profit-earning capacity, to the pre-1938 conditions, and a continuance of demand for textile machinery from this source may be expected.

THE HARLAND TRAILER FIRE PUMP.

ONE of the demands of the present disturbed times is for portable self-contained fire-extinguishing pumps, and experience has shown that a satisfactory plant can be constructed for towing by motor-cars, lorries, etc. An interesting example of a trailer fire-pump, manufactured by Messrs. The Harland Engineering Company, Limited, B.E.P. Works, Alloa, is illustrated in Figs. 1 and 2, above. From Fig. 1 it will be seen that the pumping unit is carried on a two-wheeled chassis. The frame is triangular in plan and

is braced with channel cross members, the whole being electrically welded. The engine and pump are attached to a separate frame which is mounted on the chassis frame with interposed anti-vibration blocks. The apex of the chassis frame carries the towing coupling and brake-operating gear, manhandling bars, hand brake and supporting jack, two other jacks being fitted at the rear. The towing coupling has two coil springs, viz., a heavy one for taking the pull and a lighter one to control the over-run. The brakes, of the internal expanding type with Girling shoes, are operated automatically through rods by the over-run of the trailer itself when this is being towed. A spring-loaded device ensures smooth and progressive braking action and eliminates snatching or locking of the wheels during towing. The brake hand lever provides an action sufficient to ensure positive locking of the wheels. The manhandling bars fold back when not in use. The jacks are of steel tube with adjusting and locking gear. The axle is down-swept for approximately 6 in., and the pressed wheels, 20 in. by 6½ in., are mounted on Timken taper-roller bearings. A choice of pneumatic tyres is available. The springs are of silicon-manganese steel and are clamped to the frame by U bolts.

The pump is fitted at the rear and, as will be evident from Fig. 2, is of the centrifugal type, with a central suction branch and two delivery branches on the discharge volute. It is of the firm's "Monoglide" single-stage type and both casing and impeller are of bronze. The suction branch is 4 in. in diameter and the delivery branches are 2½ in. in diameter. The suction cap is screwed but the delivery caps, as seen in the illustration, are of the instantaneous connection type, though screwed caps can be supplied. The pipe on the top of the suction branch and leading to the left is for priming the pump. It is fitted with a control cock and filter, and is connected to an ejector actuated by the exhaust gases from the engine. The lever seen to the extreme left controls a valve inserted in the exhaust pipe between the manifold and the silencer. When it is necessary to prime the pump the valve is closed, with the result that the exhaust gases are diverted through the ejector, creating a vacuum in the pump and suction pipe. When water has entered, which is ascertained from the combined vacuum and pressure gauge on the right, the valve is opened and the exhaust gases pass through the silencer in the ordinary way. The gauge to the right indicates the pressure at the delivery branches in normal working. The smaller gauge in the centre indicates the engine lubricating-oil pressure. While referring to this control panel, it may be noted that the engine ignition switch is situated immediately below the oil-pressure gauge. The throttle and choke levers are behind the left-hand delivery valve. The small drum near the right-hand delivery valve is the cooling-water filter.

The engine is of the Meadows four-cylinder four-stroke cycle type, with cylinders 95 mm. bore by 130 mm. stroke, and running on petrol. The cylinders are of the monobloc type with a detachable head. Overhead valves of nickel steel, hardened and ground, with push-rod and rocker operation, are fitted, the gear being protected by a detachable aluminium cover. The crankcase, of a very stiff and rigid design, is divided longitudinally. The crankshaft is stamped from high-tensile steel and is ground on the pins and journals, the latter running in three die-cast white-metal bearings. The connecting rods are Duralumin stampings of H-section. The big-end bearings are of bronze with die-cast white-metal linings, and have keeps and nickel-steel fitted bolts. The small-end bearings have floating bushes on the hardened and ground steel gudgeons. The pistons are of die-cast aluminium with three compression rings and one scraper ring. The piston and rod assemblies are balanced to secure uniformity in weight, the crankshaft being dynamically balanced. A petrol pump is fitted on the crankcase, and is operated by a push rod from the camshaft. It has also a finger-operated lever to prime the carburettor when starting up. The carburettor is of the Solex governor type, and is set to operate at 5 per cent. above the maximum service speed. Ignition is by a Scintilla Vertex magneto with automatic advance control and an impulse device for easy starting.

As will have been gathered from a reference to the cooling-water filter made previously, the cylinders and head are water-jacketed. The filter, however, is not on the circuit to these parts, but on a pipe leading to a coil immersed in the circulating-water tank. This pipe leads from the discharge side of the centrifugal pump, so that a stream of water is sent through the coil to waste, the circulating water being thus kept cool; a valve on the supply pipe regulates the flow. The water tank is of copper and has a capacity of 6½ gallons; it is situated under the engine bonnet. The jacket water is circulated from the tank partly by thermo-syphon action and partly by a pump of the impeller type situated on the cylinder head and driven by belt from the camshaft. Additional engine cooling, particularly of the oil sump and external fittings, is provided by a fan directly driven by an extension of the crankshaft. The petrol tank is situated under the bonnet, adjacent to the cooling-water tank. It is made of lead-coated steel plate and has a capacity of approximately 11 gallons, *i.e.*, sufficient for a minimum of two-hours' running at full duty. Forced lubrication is provided for each heavily-loaded working point of the engine, the oil being drawn from the sump by a submerged gear-type pump, and delivered at a regulated pressure of between 20 lb. and 30 lb. per square inch. The sump capacity is 1½ gallons. The oil pump is driven by spiral gears from the camshaft and effective filtering arrangements are provided.

As regards performance, the plant is very flexible. If six ⅝-in. nozzles are employed, the total delivery is 480 gallons per minute to a height of 70 ft., *i.e.*, 80 gallons per minute per jet. With two 1-in. nozzles, a total delivery of 460 gallons per minute to a height of 92 ft. can be obtained. The total delivery with four ¾-in. nozzles or three ¾-in. nozzles is 480 gallons per minute to a height of 80 ft. for the first mentioned and to 84 ft. for the last. At this delivery the engine speed is about 2,200 r.p.m., the drive being direct and not through gears. At the 480 gallons per minute delivery the delivery pressure is 80 lb. per square inch at 85 per cent. of the engine power. This delivery is with approximately 10 ft. of suction lift. With the maximum static suction lift of 24 ft., the delivery is 260 gallons per minute. The equipment may be varied, that shown in Fig. 1 being a typical one, and, briefly, comprising two 15-ft. lengths of 4-in. armoured suction hose with strainer, adaptors, etc., two 100-ft. lengths of 2½-in. canvas delivery hose with Y-piece, and four branch pipes and nozzles. The suction hose is carried as shown, the other parts being stowed in two cupboards at the front of the trailer. The variations in equipment naturally affect the total weight of the plant, which may thus range from 17 cwt. to 20 cwt. approximately. It may be mentioned, in conclusion, that the trailer complies in all respects with the requirements of H.M. Office of Works.

MODERN HIGH-PRESSURE WATER-TUBE BOILERS.

ALTHOUGH the different types of modern high-pressure water-tube boilers have been described and illustrated separately in these columns from time to time, few comparative accounts have hitherto been presented. Such an account, however, was given in a paper entitled "High Pressure and Forced Circulation Boilers," by Dr. R. Pendennis Wallis, M.Sc., M.Inst.C.E., read before the London Technical Group of the Electrical Power Engineers Association on Tuesday, January 9, 1940. A summary of this paper is given below.

Dr. Wallis commenced with a reminder that in all natural-circulation boilers the circulation depends on the difference in density of a column of steam and water mixed in the steam-raising tubes and a column of cooler water in the downcomers. With an adequate economiser, the water is fed to the boiler at a temperature approximating to boiling point, the difference in density of the two columns being thus largely dependent upon the difference in density of steam and water. This difference, at boiling point, becomes less as the pressure increases; thus, at 2,000 lb. per square inch, it is only 60 per cent. of that at 200 lb. per square inch, while at the critical pressure of 3,200 lb. per square inch both steam and water have the same density, viz., 20·1 lb. per cubic foot. In low-pressure boilers, where the difference in density of steam and water is great, it is unnecessary to pay much attention to the height of the column creating the natural circulation, but with increasing pressure the steam-water drum has to be placed at a considerable height above the steam-raising elements. This point was illustrated by a diagram of the Babcock and Wilcox high-head type of boiler,* having a large combustion chamber, the upper part of which is fitted with Bailey water walls and is surmounted by the straight-tube evaporating elements.

Above this is a large economiser of the straight-tube type, illustrated in ENGINEERING, vol. 148, page 496 (1939), and a large hair-pin tube type superheater, the steam-water drum being above both these auxiliaries and therefore a considerable height above the steam-raising tubes which, moreover, are decreased in number compared with the low-pressure type of boiler, while the economiser surface is increased. The proportions of the several parts of this type of boiler lead to a consideration of the division of the heat of combustion between the economiser and generating tubes, the critical-pressure operating Benson† boiler being used as an illustration.

In the temperature-entropy diagram, Fig. 3, on the opposite page (the figure numbers of the paper being retained), at a pressure of 200 lb. per square inch the area A B C D corresponds to the sensible heat required to raise the feed water from its initial temperature, say, 250 deg. F., to the boiling point, 382 deg. F. The area D C E F corresponds to the latent heat that has to be added to convert the water into steam, this area being six times that corresponding to the sensible heat. Considering the extreme condition in which steam is raised at the critical pressure of 3,200 lb. per square inch, there is no latent heat and steam is generated from the feed water by the addition of sensible heat only. The area A B G H on the diagram corresponds to this sensible heat. The graph, Fig. 4, shows the heat in water and steam at various pressures, and the ratio of the sensible heat to the total heat, and from this it is seen that, as the pressure increases, the proportion of boiler heating surface to economiser heating surface must decrease. At the critical pressure, the sensible heat is 100 per cent. of the total heat of steam formation, and the plant is completely lacking in boiler tubes in the ordinary sense of the term. The generator virtually becomes a large economiser followed by a superheater. In the Benson steam generator, the feed water enters the bottom of a vertical helical coil, at the top of which the superheated steam leaves. The actual position of steam formation will vary with the load, and this renders it impossible to say exactly how much of the tube-coil is economiser and how much is superheater.

The paper contains illustrations of both the Benson boilers at the Gartenfeld Cable Works of Messrs. Siemens-Schuckert, and states that, as the result of operating experience, the firm decided that the boilers could be successfully operated at pressures below the critical pressure, the determining factor being that this change would reduce the power required for the feed pumps. The operating cycle was naturally somewhat altered by this reduction of pressure, since there was a portion of the circuit where latent heat was added and where ebullition took place. The tubes in this portion were subject to indeterminate rates of heat transfer, since at one moment they might be filled with water and at the next contain steam. This difficulty was overcome by placing this conversion zone in the later gas passes, where the combustion temperature was not high enough to cause serious overheating of the tubes.

In the Ramzin boiler, developed in Russia and illustrated diagrammatically in Fig. 8, opposite, trouble does not appear to have arisen from this source, and the conversion from water to saturated steam takes place in the hottest part of the furnace. The combustion of oil or pulverised fuel takes place in the left-hand chamber, the products passing vertically upwards through the right-hand chamber. The tubes of the left-hand chamber are supported on some of the economiser tubes, which hang vertically. The horizontal tubes forming the walls comprise the radiant economiser, the evaporating section and the radiant superheater. The convection superheater is hung vertically in the duct between the two chambers. The right-hand chamber contains convection economiser tubes, steam reheater tubes, and a plate-type air heater. Dust hoppers are provided.

The nature of the feed water as affecting boiler design was next discussed in the paper. Boilers such as the Benson boiler, or Ramzin boiler, when employed in a generating station, are likely to be fed with distilled and de-aerated water, only some 2 per cent. of similar water being required as make-up. But, in an installation where back-pressure or pass-out engines are used to provide both power and process steam, the feed make-up may be anything from 50 per cent. to 100 per cent., and in such cases the feed consists of chemically-treated water containing a definite amount of salts. The ultimate deposition of these salts on the inside of the tube coils is dealt with by isolating one of the 6 or 8 parallel paths into which the boilers are usually divided and washing it out with clean hot water. The paths are cleaned successively so that the boiler continues at work throughout the whole operation.

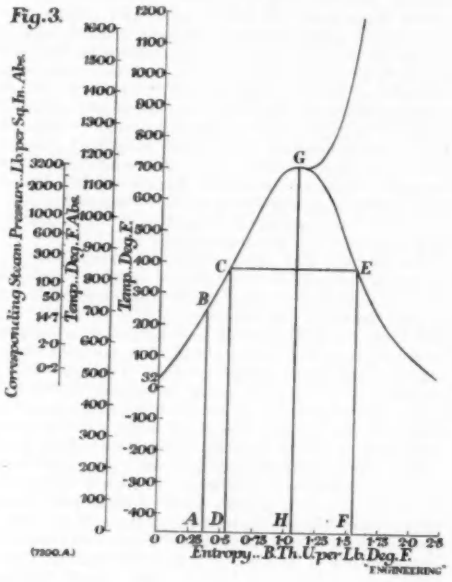
The method, successful in practice, demands care and vigilance and in the Sulzer Monotube boiler,* in which the water is forced once through the coil and not re-circulated, as, indeed, is the case with the Benson and Ramzin boilers, a different procedure is adopted. This consists of a discharge, either intermittent or continuous, of that portion of the boiler water in which salt concentration is becoming too high. The "spill over" or "salt interceptor" for effecting this is briefly described in the paper and immediately following this description is an account of one of the several ways of effecting thermostatic control of forced-flow boilers, the particular method described being one in which regulation is carried out in two stages, a coarse adjustment being effected from the temperature

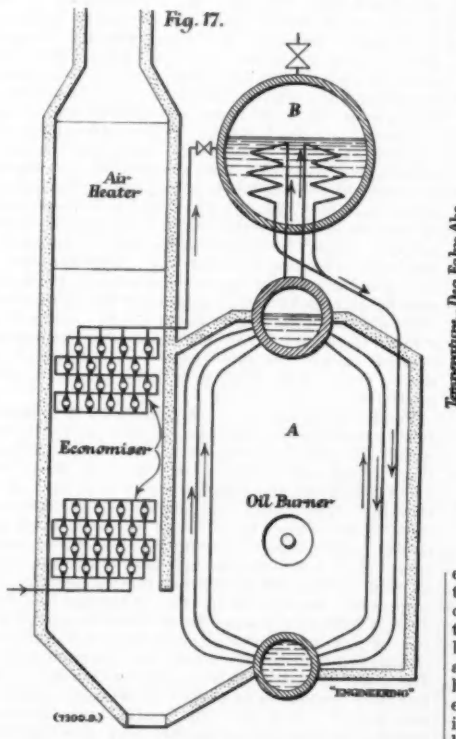
* See ENGINEERING, vol. 142, page 596, *et seq* (1936).
† *Ibid.*, vol. 129, page 89 (1930).

* See ENGINEERING, vol. 141, page 220, *et seq.*

of the steam at a point between the evaporating surface outlet and the superheater inlet, and the final close regulation from the temperature at a point on the superheater outlet. The control is effected not only by the temperatures at the points mentioned, but also by the rate at which the temperature changes.

As an example of the multiple-circuit boiler, with coils arranged in parallel, Dr. Wallis took the La Mont boiler,* which he described as a bold facing of the difficulty of avoiding either a high hydraulic loss from the use of a small number of long coils or uncertainty of the circulation if many coils are arranged



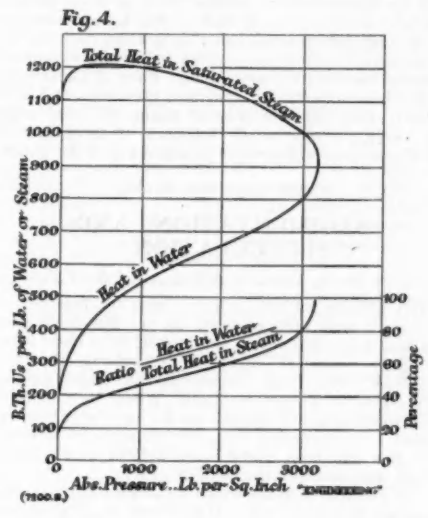


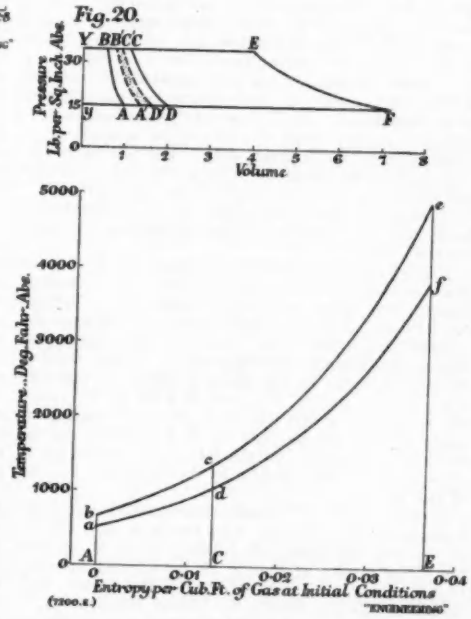
in parallel. The feed water is kept in continuous movement by a special circulating pump which runs at a constant speed, irrespective of the boiler load, and delivers eight times to ten times the water that can be evaporated at full load. The pump delivers the water to distribution headers at a pressure of approximately 35 lb. per square inch above the pressure in the steam-water drum, the point of connection of the different coils to the headers being provided with nozzles of a size which ensures that the flow of water through each coil is proportional to the heat absorption capacity of that particular coil. The amount of water supplied is large enough to ensure a thorough wetting

* See ENGINEERING, vol. 144, page 594 (1937), vol. 146, page 414, *et seq.* (1938).

of the internal surface, thus protecting the tubes against overheating. The steam and excess of water is discharged into the drum above the water line, the steam then passing to the superheater and the water beginning its circuit through the coils again. The feed water is introduced to the drum after passing through an economiser, and the coil connections enter the drums at a sufficiently high level to permit sludge to accumulate in the bottom of the drum out of the way of the downward flow.

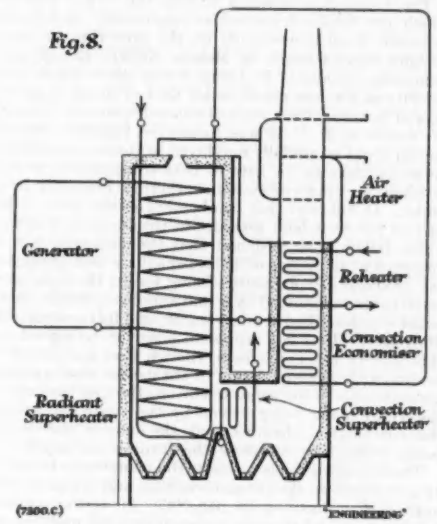
In the La Mont boiler, control of the temperature of the tube metal is secured by circulating a large





excess of water through the individual circuits, but the same end is reached in the Loeffler boiler* by circulating superheated steam through the coils forming the radiation portion and first convection pass in the boiler, the velocity being kept at a figure which ensures a high rate of heat transfer without overheating. A high-pressure feed pump forces the water through an economiser to a drum in which superheated steam is introduced. The heat liberated by this steam provides latent heat for evaporating the feed water, the saturated steam thus produced being drawn from the drum by a circulating pump and delivered to the radiation tubes forming the walls of the combustion chamber and through the convection superheater bank of tubes. About one-third of the superheated steam from these tubes is delivered to the main stop valve for external use, the remaining two-thirds being bubbled through the feed water in the drum. The work done by the circulating pump is proportional to both the resistance of the coil circuits and to the volume of the fluid pump and, therefore, for a given output, by weight, of steam per hour, the pumping power is inversely proportional to the density of the steam. For this reason the Loeffler boiler is particularly suitable for high

* See ENGINEERING, vol. 147, page 614, *et seq.* (1939).



pressures and most of these boilers at present in existence are operated at a pressure of about 1,900 lb. per square inch.

At this point the author discussed the temperature difference between the inner and outer surfaces of the radiation tubes in the combustion chamber of the modern high-pressure coil boiler. This difference is proportional to the heat transferred and the thickness of the tube and is inversely proportional to the thermal conductivity of the metal. With tubes 2 in. in external diameter, the thickness of the metal would be about ¼ in., these proportions indicating that, when calculating the stress due to an internal pressure of, say, 2,000 lb. per square inch, the tube should be regarded as a thick cylinder. A diagram was given showing that the maximum tensile stress due to the internal pressure occurs at the inner wall and this is also the position of the maximum tensile stress due to the heat transmission. The maximum permissible stress depends upon the rate of creep of the steel at the metal temperature. Although various alloy steels present advantages from the point of view of creep, these may be offset by a lower thermal conductivity; a 0·26 per cent. carbon steel will transmit 400 B.Th.U. per square foot per hour per deg. F. per inch thick; a carbon steel with 0·5 per cent. molybdenum will transmit only 240 B.Th.U., and an 18 per cent. chromium and 8 per cent. nickel steel only 114 B.Th.U. Molybdenum steel is being increasingly used for superheater tubes, but the figures just cited show that the temperature drop through the metal for a given heat transfer is more than 50 per cent. greater than with an ordinary steel. The distribution of stress indicated in the diagram in the paper assumes that the radiant heat is absorbed equally on the whole circumference of the tube, a condition which does not invariably obtain. It is sometimes contended that, in view of the large evaporating drum of the Loeffler boiler, the matter of the purity of the feed water does not demand such scrupulous attention as is required in some other types, but although sludge can accumulate in the drum and be periodically removed therefrom, small globules of water in suspension in the steam can carry and deposit scale on the interior of the tubes, the presence of even the thinnest film of such scale increasing the temperature of the metal and lowering its permissible creep stress.

It is stated in the paper that the elimination of scale-forming products from the water circulating in the tubes exposed to the greatest heat is the cardinal principle of the design of the Schmidt-Hartmann boiler, a diagrammatic view of which is reproduced in Fig. 17, adjoining. Steam is generated at high pressure from distilled de-aerated water in a closed circuit in the primary boiler A. The circulation is of the natural head type and the steam leaving the top drum of the primary boiler passes through coils in the water space of drum B of the secondary boiler, the condensate returning by downcomer tubes to the bottom drum of the primary boiler. The water in drum B is evaporated by the steam in the coils giving up its latent heat, and the steam in this drum is at a lower pressure than that in the primary boiler, since it is necessary to maintain a temperature difference of about 60 deg. F. between the primary and secondary boiling points. As there is only a small head of water above the evaporator coils and there are no currents due to discharging riser tubes, the evaporation in drum B is very quiet and steady and the steam leaving this drum contains only a small amount of moisture. The water in the drum is

first passed through an economiser and no special precautions regarding purity of the feed are, in general, necessary. The boiler is, therefore, particularly suitable for plants requiring process steam in which little or no condensate is returned to the boiler feed system. Although the heat has to be passed through two metal walls in series, it is found, in practice, that in the evaporator coils a heat transfer of 480 B.Th.U. per square foot per hour per deg. F. temperature difference can be obtained, and this corresponds to an evaporation of about 30 lb. per square foot of heating surface.

The boiler next referred to was the Velox boiler,* which Dr. Wallis described as originating, as regards principle, from experiments on the flow through gas-turbine nozzles made by Messrs. Brown, Boveri and Company, Limited, it being found that when the velocity of the hot gas exceeded that of sound, a much greater heat loss than was anticipated occurred through the nozzle walls. It was considered that this phenomenon could be usefully employed in steam generation, an an increase in the rate of heat transmission would result in an appreciably higher thermal efficiency in a boiler. It followed that combustion would have to be carried out at a high pressure in the furnace, and the Velox boiler is so designed that the necessary air is delivered at a pressure of 35 lb. per square inch absolute, the products of combustion being forced through very small tubes surrounded by a thin annulus of water. The boiler was described at some length, and its construction illustrated. It is not proposed, however, to reproduce this part of the paper here, though that section of it dealing with the application of the gas turbine to steam generation calls for some attention, the gas turbine in the Velox boiler being driven by the waste gases from the combustion chamber and the power developed being utilised to compress the furnace air supply.

The operating cycle of the turbo-compressor installation is shown in the pressure-volume and temperature-entropy diagrams, Fig. 20, page 247. Air at atmospheric temperature and pressure is drawn into the multi-stage compressor and adiabatically compressed from 15 lb. per square inch absolute to 35 lb. per square inch absolute, along the line A B. At B its volume is a little more than half the original volume, and the temperature has been raised from 70 deg. F. to 200 deg. F. After delivery in the combustion chamber, it is heated at constant pressure, by the combustion of the fuel, along the line B E. The temperature of the products of combustion is higher than the turbine blades could withstand were it not that the gas is cooled in the combustion chamber and superheater at approximately constant pressure along the line E C, the tube surface of these parts in the boiler being so proportioned and designed that the gas is cooled to 900 deg. F. at the inlet to the turbine. In the turbine the gas is adiabatically expanded from C to D, its temperature falling from 900 deg. F. to 700 deg. F. The point D is that of discharge through the economiser to the atmosphere, and the gas can be considered to be cooled at constant pressure along the line D A. The total heat available in the process of cooling the gases from E to C is represented on the T ϕ diagram by the area e E C c, this heat being utilised in generating and superheating the steam. The total amount of heat rejected in the isobaric compression D A is represented by the area d C A a and a portion of this is utilised in preheating the water in the economiser.

In the design of the turbo-compressor plant consideration must be given to the relation in the theoretical cycle between the negative work done by the compressor and the positive work done by the turbine; also of the effect of the mechanical efficiency or inefficiency of these two machines on the net output of the turbine. The work done to compress the air and to deliver it into the combustion chamber against the higher pressure is represented on the pressure-volume diagram by the area A B Y y. The useful work performed in the turbine is represented by Y C D y. If both the compressor and the turbine had a mechanical efficiency of 100 per cent., the net useful work would be represented by the area A B C D. Assuming the mechanical efficiency of the compressor to be 73 per cent., the external work required to effect the compression and delivery represented by A B Y y is equal to $\frac{1}{0{\cdot}73}$ A B Y y, *i.e.*, 1·37 A B Y y. This area may be represented on the pressure-volume diagram by A′ B′ Y y. The theoretical useful work done by the turbine is represented by Y C D y. The mechanical efficiency of the turbine may be taken at about 83 per cent., and the area Y C′ D′ y may represent 0·83 Y C D y. The net available work is thus A′ B′ C′ D′. The mechanical efficiencies here given are the best actually obtained at present with large installations. The plant is usually designed with a small deficiency of driving power, which is made good by a starting motor. By slight variations of the electric supply to this motor a very rapid response to change of load on the boiler can be obtained.

* See ENGINEERING, vol. 137, page 469, *et seq.* (1934).

The paper concluded by a brief analysis of the reasons for the adoption of the forced-circulation boiler. It was held that the question of thermal efficiency was not a decisive factor, since the efficiency of any boiler plant depended very largely upon the chimney losses, which can be assessed by the CO_2 content of the flue gases and their temperature at the chimney base. The CO_2 depends upon the efficiency of combustion in the furnace and the gas-tightness of the boiler, economiser and air-heater casing and connecting ducting. The flue-gas exit temperature depends on the extent and efficiency of the economiser and air-heater heating surface, and is thus largely independent of the type of boiler. The main advantage of the forced-circulation boiler, it is concluded, lies in its increased output for a given space and weight of material used in its construction. Each of the several boilers has its particular sphere of usefulness and it is unlikely that any one type of boiler will ever meet the varying needs of all branches of industry. A fairly complete bibliography is appended to the paper.

SEDIMENTATION AND FLOCCULATION.*

By M. B. DONALD, M.Sc., A.R.C.S., F.I.C.

THE relation between sedimentation and flocculation is a very close one, although as yet the connection has not been sufficiently established in a clear form to guide chemical engineers in solving practical problems. This paper represents an endeavour to summarise the present position. Where theories have been conflicting, the original results have been redetermined experimentally or a new experiment devised, and this has been found very helpful in obtaining a true perspective of the problem.

The conditions under which thixotropy occurs differ considerably from those laid down by Freundlich. The process of sedimentation can be roughly divided into two main parts. When solids settle in liquids there comes a time when the rate of settling drops suddenly from a comparatively fast to a relatively slow value. This point will be designated the "critical point." Out of this fact there emerge two main factors to be considered. The first is the "rate of sedimentation," since this affects the area of the sedimentation tank required for a given duty. The second is the "sedimentation volume." This is the volume of the settled solid when it has reached the "critical point" and its value affects the height of the sedimentation tank and the capacity of the subsequent handling devices.

Rate of Sedimentation.—With regard to the rate of sedimentation, it is found that, above a given concentration, the solids in a slurry settle with a definite top level surface demarking the settling solids from the supernatant liquid. This gives an easy method of determining the rate experimentally. It is natural to attempt to apply to the figures obtained in this way some form of Stokes' law, and in 1909 H. E. Ashley was able to show that the results of some experiments made in the previous year by H. S. Nichols, on the effect of temperature on the rate of sedimentation of clays, could be accounted for by the change in viscosity of the water.

Nichols had also made experiments with clay flocculated with sulphuric acid and with clay slurries of various concentrations. Ashley tried to explain the latter results as due to an increase of viscosity of the slurry with concentration. He quotes some results obtained in 1908 in the United States, by A. V. Bleininger, who used Coulomb's method of an oscillating disc suspended by a wire. Extruding the clay slurry under constant pressure through a 2-mm. aperture had been found to give unsatisfactory results. The improved figures are not nearly sufficient to account for the difference in rates of sedimentation. The Coulomb method, however, is open to the objection that the rate of shear is continuously varying and that, by taking the amplitudes of the initial swings, the viscosity is measured at high average rates of shear. As will be seen later, the apparent viscosity of flocculated solids in suspensions decreases rapidly as the rate of shear increases. C. S. Robinson, in 1926, also made the suggestion that the gravitational force should be taken as the difference between the density of the solid and the slurry and not between the solid and the pure liquid. This suggestion, however, is quite inadequate to explain the 450-fold increase in the rate of sedimentation of kieselguhr in alcohol over its rate in water. The viscosities of these two fluids are in the ratio of 0·012 poise to 0·010 poise.

When considering the question of flocculation, R. F. Stewart and E. J. Roberts pointed out, in 1933, that the aggregation of 1,000 particles into a single floc is likely to increase the rate of sedimentation 100 times, and even if the floc is 99 per cent. water by volume, by 22 times. The evidence all points to the fact that the chief explanation of the anomalous results is an increase in floc size, either by the greater concentration of the solid increasing the chance of particles touching or by the action of the liquid phase. This aspect was considered in 1906 by E. Buckingham. He determined the rate of settling of quartz flour, titanium dioxide and soils in water, 95 per cent. alcohol, acetone, amyl alcohol, aniline, ethyl acetate, chloroform, ether, carbon disulphide, benzene, toluene and zylene. By tabulating various properties, density, surface tension against air, viscosity, specific conductance, and dielectric constant, he was able to dismiss the first two; viscosity only played a minor role and there was no means of distinguishing between the last two properties since they ran parallel. He examined Coehn's statement that when a liquid and a solid are in contact the one with the greater dielectric constant becomes positively charged. Although titanium dioxide (rutile) has a much higher dielectric constant than water and should, therefore, be positive, it migrated in the opposite direction, *i.e.*, as if it were negative.

The formation of suitable flocs has been the object of much research in waterworks practice, where a suitably sized and compact floc is often essential in the proper treatment of water by certain methods. It has been found that it is first necessary to obtain thorough dispersion of the chemical in the water by a vigorous and short initial mixing. Subsequently, a gentle flow of about 30 cm. to 40 cm. per second has been found to give the optimum conditions for coagulation. A lower velocity requires a longer time of treatment and a higher velocity gives flocs which only reach a fraction of the optimum size. An overdosage of chemical forms a fragile floc. Recent work, recorded by Tomalin in 1938, on the flocculation of coal suspensions, shows that with organic flocculating agents, such as starch and gelatine, there is an optimum concentration of reagent at which the sedimentation rate rises to a maximum. Some light on this behaviour is supplied by v. Buzagh. He experimented on the flocculation of silica, clay, and bentonite particles by means of gelatine. He determined the bonding force by allowing the particles to settle one layer thick on a surface and then gradually inclining the surface until there was a slip—indicated by a wave-like motion. The greater the angle before the slipping took place the greater was the bonding. In a similar manner he found that, when equilibrium had been reached, there was a particular concentration of the reagent at which the bonding forces were greatest. A further observation by v. Buzagh was that, at concentrations of gelatine just above that which gave the maximum bonding value, the angle determined immediately was large, indicating good bonding. With subsequent determinations at the same concentration, the angle steadily decreased to an equilibrium value. This time-effect was only noticed in a short range of concentrations greater than that giving the maximum equilibrium bonding value. The time effect would appear to be due to the gradual diffusion of more gelatine to the interfacial surface.

Further evidence on the formation of flocs comes from experiments with sewage and with mud. Recent work on conditions in the estuary of a river,* showed that, during sedimentation, the fine particles collide and the size and the velocity of the flocs increase as they fall. The average velocity of sedimentation for these dilute suspensions increased as the depth of the column was increased up to 40 ft., the greatest depth tried. The sedimentation rate also increased, with increase in the initial concentration of mud in the suspension, possibly since the individual particles did not have to diffuse so far to form the flocs. The size of aggregates was greatest with slow rates of stirring just sufficient to maintain the flocs in suspension. The flocs formed in this manner were very fragile and were broken up immediately the mud suspension was stirred vigorously. The picture that is being obtained of flocculation is that of a bonding force between the particles which can be ruptured mechanically.

For much thicker clay suspensions, M. B. Donald found that the rate of sedimentation had a constant value up to the critical point if the clays were peptised with alkali, whereas if they were flocculated with acid the rate of sedimentation accelerated with time. This acceleration was not to be expected, since the slurry was becoming more concentrated as it settled, but it did show that the effect of flocculation was very marked. The amount of acceleration should afford a means of estimating the degree of flocculation.

The fact that flocculation takes places does not eliminate Stokes' law from consideration; it only

* Paper prepared for the Second Chemical Engineering Congress of the World Power Conference which was to have been held in Berlin in June, 1940. The paper was read in London before the Institution of Chemical Engineers, on February 13, 1940. Abridged.

* *Water Pollution Research Tech. Paper No.* 7. H.M Stationery Office, 1938.

means that care must be taken in applying it. An attempt was made to correlate the rate of sedimentation and the viscosity of the slurry. A trial was made of the method given by E. C. Bingham and T. C. Durham* using a Bingham and Jackson modification of the Ostwald standard viscometer and a standard air pressure. It was found that peptised clay slurries gave reasonably concordant results except at rather high concentrations. It was impossible to repeat any results, however, with the flocculated clay slurries. The time which elapsed in changing the direction of the flow of the fluid (or in maintaining it stationary) or the air pressure affected the results in that they gave an opportunity for the bonds to be formed or ruptured in different degrees. This effect of structural viscosity had been noticed, in 1924, by H. Freundlich and E. Schalek, with suspensions of Baumwollgelb and Benzopurpurin, and in 1926, by E. Hatschek and R. S. Jane, with rice starch in a mixture of carbon tetrachloride and B.P. paraffin adjusted to the same density as the starch. In both cases it had been measured in a Couette concentric-cylinder viscometer. This instrument, unlike the Ostwald viscometer, measures the viscosity of the liquid under equilibrium conditions but suffers from the disadvantage that it cannot measure the viscosity of suspensions that tend to settle out. The result of these experiments was that it was found that the apparent viscosity increased as the rate of shear (*i.e.*, the velocity of rotation of the cylinder) decreased, and was not independent of it as with normal fluids.

This structural viscosity implies, as stated by C. F. Goodeve and G. W. Whitfield, a spontaneous building up of internal structure and its breakdown due to shear. With a capillary viscometer and a flocculated solid, the rate of building up of the internal structure is often so fast that it has attained a considerable magnitude in the very short space of time which elapses between drawing the suspension to the flow side of the viscometer and applying the air pressure to force it back to make the measurement. Owing to the difficulty of designing a viscometer to give results on a settling slurry, at the very small rates of shear which occur when measuring rates of sedimentation, it has been impossible to apply Stokes' law so far.

The accelerating rate of sedimentation for flocculated particles may be due to the formation of larger flocs, as was the case in experiments with dilute sewage suspensions, or it may be that in the more concentrated slurries the flocs have formed a loose structure below and this is being broken down as more solid is being piled up upon it from above. From the formation of channels which are visible in thick slurries it might appear that there is some justification for this suggestion. A practical aspect of the accelerating rate of settling is contained in the observation by R. T. Mishler, in 1912, that thick slimes settle appreciably faster in deeper vessels. Other factors affect the rate of settling and these will appear when considering the question of sedimentation volume, since flocculated solids settle rapidly and have a large volume, and peptised solids settle slowly and have a small volume.

Sedimentation Volume.—In the packing of comparatively large aggregates, such as, for example, the sand used in making concrete, the percentage of the total bulk volume which exists as interspaces between the solid particles is roughly 40 per cent. This means that the bulk volume of the sand is 1·67 times larger than its actual volume. Moreover, in practice, it is found that the value obtained for approximately even-sized grains does not differ very much from this mean value. As the particle size becomes smaller the bulk volume may become proportionately greater. Certain grades of very fine zinc oxide, for example, after settling in water, will occupy a space twenty-five times larger than their actual solid volume.

Earlier researches on sedimentation volume each considered only one solid. Thus, sand was used by Atterburg (1908); clay with various electrolytes, by Pickering (1917); the volume of coal in solvents by Pavlov (1927); and red lead in solvents by Blom (1927). Blom used two types of red lead, and carbon tetrachloride, chloroform, petroleum ether, toluene, ether, benzene, acetone, alcohol and methyl alcohol. He found that there was a parallelism between the sedimentation volume and the value for the heat of wetting of the particular solvent with respect to clay. This observation is of great importance since if it is true (and subsequent experiments seem to confirm it) it opens up a thermodynamical approach to problems of flocculation. Blom also showed that for these solvents the sedimentation volume is roughly proportional to the logarithm of the latent heat of vaporisation. Even with the introduction of a logarithmic scale the points do not fall on the line. The suggestion, however, is interesting since the surface energy, as determined in the manner first shown, in 1858, by Lord Kelvin from the rate of change of surface tension with temperature, varies from temperature in a manner similar to the latent heat of vaporisation; both become zero at the critical temperature. Blom also showed that small amounts of linseed oil in benzene lowered the sedimentation volume of red lead considerably. The results of this observation will become more apparent as later work is considered.

A very extensive research was undertaken in 1929 by Ostwald and Haller.* They determined the volume of talc, fullers earth, alumina, silica, magnesia, chalk, iron oxide, graphite and a variety of activated charcoal in various organic liquids, and found that it was largest in carbon tetrachloride (2·2), then hexane (1·9), benzene (2·3), chloroform (5·2), ether (4·3), acetic acid (6·5), alcohol (25·8), acetone (20·7), and water (81·1). The figures in brackets indicate the dielectric constants and it will be seen that the largest volumes are in the non-polar liquids. They investigated this point more thoroughly with graphite and talc in fifty different liquids and showed that, although there are exceptions, there was a distinct parallelism. This work is in agreement with Buckingham's work on rate of sedimentation and it was confirmed by American workers three years later (1932) with titanium dioxide in twenty-five organic liquids. It is a conclusion which, however, must be accepted with some reserve, since it will be shown later that surface effects are more important and a sample of zinc oxide tested recently was found to give the largest volume in water, then ethyl alcohol and the smallest in paraffin (kerosene); this is the reverse effect.

The predominating cause of variation in sedimentation volumes would appear to be the surface film. Ostwald and Haller found that, when drying graphite and charcoal and the liquids, smaller sedimentation volumes were obtained and this was confirmed by the American workers especially with regard to the effect of water in benzene. The addition of a trace of water to benzene almost doubled the volume of a sample of titanium dioxide from 10·5 times its solid volume to 20·1 times. The water would not materially affect the dielectric constant of the benzene. The controlled addition of very small amounts of metallic soaps or stearic acid to titanium oxide in benzene lowered the volume from 15·6 to about 6·0.

TABLE I.

Initial Concentration.	Final Volume.	Final Volume in cc. per 100 gm.
Per cent.	cc.	
2·5	107	428
7·5	239	319
15·0	388	249
30·0	618	206

With regard to the relation between wetting and flocculation it is of interest to compare the findings of flotation practice. R. Rabone, in *Flotation Plant Practice*, says (page 64): "Since substances which can be flocculated can usually be floated, and vice versa, the terms 'flocculated' and 'deflocculated' have become more or less synonymous with 'floatable' and 'unfloatable' and should be understood in this sense, even though the particles of ore often become unfloatable in practice while still slightly flocculated, that is, before the point of actual deflocculation has been reached."

There are certain purely mechanical effects to be taken into account considering sedimentation volume. These are the effects of gravitational forces due to the difference in density between the solid and the liquid. In 1916, Free† determined the volume of kaolin after settling from slurries, varying from 2·5 per cent. up to 30 per cent., and found that the thicker the slurry the more compact was the final volume, as is shown in Table I. It is obvious from these figures that with a flocculated slurry the effect of the gravitational forces due to difference in density causes closest packing where the final volume, and hence the total weight, is greatest. A confirmation of these results was carried one stage farther by Ostwald and Haller, who centrifuged sediments and found that although the volumes were smaller than those obtained by natural settling yet they were still in the same order series. In practice, a similar effect has been noticed by J. V. N. Dorr, to whom is attributed the statement that deep tanks have the advantage of yielding a thicker discharge than shallow tanks.

The question of the structure of flocculated solids also enters into problems of filtration. In determining the resistance to flow of filtrate through filter cakes it is found that the resistance sometimes increases as more pressure is applied to the filtrate to force it through. These cakes are known as compressible filter cakes and, in 1934, P. C. Carman came to the conclusion that the compressibility was directly related to the degree of flocculation. The more flocculated the filter cake the more easily will it tend to be compressed under external mechanical forces.

An interesting corollary of the tendency to variation of the sedimentation volume is the variation of the amount of different liquids absorbed by the same quantity of solid. For example, Freundlich and Sachs found, in 1929, that quite different volumes of water, cumene, and cyclohexane were absorbed by the same quantity of kaolin and that there was a parallelism between the volume of liquid absorbed and the volume of sediment. With kaolin and water they found that potassium cyanide gave the greatest flocculation, *i.e.*, highest rates of sedimentation and greatest sedimentation volume. The other salts could be arranged in a "lyotropic series" if they were tested at equivalent concentrations and the order was KCN, KI, KCNS, KNO_3, KB_2, KCl, K_2SO_4 $(NH_4)SO_4$, Li_2SO_4. This type of series is also known by Hofmeister's name.* He used N/4 and stronger solutions to determine the swelling of gelatine in salt solutions. He showed that variations in the swelling occurred by maintaining either the anion or cation constant and altering the nature of the other ion.

The work of v. Büzagh on the adhesive forces in flocculated solids has already been mentioned. He also determined the sedimentation volume of sand particles down to 8 μ diameter. There was little change in the volume with particle size if pure water were used. If, however, barium chloride were added the volume increased rapidly as the particle size decreased below 36 μ diameter. With fine silica and aluminium chloride there was a maximum sedimentation volume at about 0·1 millimol concentration of the electrolyte.

Thixotropy.—It has been postulated recently by H. Freundlich that substances which are thixotropic, *i.e.*, which exhibit an isothermal sol-gel transformation, such as bentonite in water, give large sedimentation volumes. Similar results are found by H. Akamatu. The system zinc oxide in paraffin had been selected by H. Pryce-Jones† as the most popular example of thixotropy in a non-polar medium. On account of this the sedimentation volume of zinc oxide was determined in various solvents. The order was found to be greatest for water and then decreasing in ethyl alcohol, carbon tetrachloride, toluene, ether, turpentine and least in paraffin (kerosene). The last three liquids gave a slightly cloudy supernatant liquid. According to Freundlich's postulate, one would expect zinc oxide to have the largest volume in paraffin. An experimental determination of the sedimentation rates showed that zinc oxide in water gave a marked accelerating rate indicating a high degree of flocculation. In paraffin the rate was almost constant and it would thus appear that zinc oxide was thixotropic in its deflocculated condition. Correspondence with Mr. Pryce-Jones brought the suggestion from him that zinc oxide in paraffin was still flocculated to some extent since the flocs could be seen under the microscope. He showed that if the zinc oxide were mixed with blown linseed oil it could be clearly seen under the microscope to be peptised and different from the condition in paraffin.

In his book, Freundlich indicates that thixotropy is a state between coagulation and a stable sol. On this basis it would seem reasonable to assume the analogy that thixotropy is shown by systems which are in a stage intermediate between flocculation and peptisation. The extended definition of thixotropy given by Goodeve and Whitfield was "the isothermal reversible decrease of viscosity with shear"; that is to say that if a steady shearing force is applied to a fluid an equilibrium is set up between the spontaneous building up of internal structure and its breakdown due to the shearing force. If the internal structure is built up very rapidly as in highly-flocculated suspensions or very slowly as in almost peptised suspensions, the equilibrium will be so much displaced to one side or the other as not to give rise to any noticeable effects. However, if the rate of building up of internal structure takes up an intermediate and finite value, then the remarkable phenomena known as thixotropy becomes more evident to the observer. This view of thixotropy would also indicate that it is essentially an intermediate state between flocculation and deflocculation, *i.e.*, between large and small sedimentation volumes.

SCIENCE IN WAR TIME.—The British Association, Burlington House, London, W.1, is arranging a conference on "Science in National and International Aspects," to be held at Reading from July 24 to 26. This will take the place of the ordinary annual meeting, which, in normal circumstances, would have been held at Newcastle.

* See *Amer. Chem. Jl.*, vol. 46, page 278 (1911).

* See *Koll. Chem. Z.*, vol. 29, page 379 (1929).

† E. E. Free, *Eng. Min. Jl.*, vol. 101, page 681 (1916).

* F. Hofmeister, *Arch. Exp. Path.*, vol. 24, page 247 (1888); Coll. Symp. Monogr. V., page 179 (1928).

† See *Jl. Oil. Col. Chem. Assn.*, vol. 17, page 305 (1934).

CENTRALISED CONTROL OF A COAL-WASHING PLANT.

On installations employing a large number of electric motors distributed over a wide area or on several floors, it is often both expedient and convenient to employ a centralised system of control, instead of mounting each individual starter in close proximity to its motor. An example of this form of control, as applied to coal-washing plant, is provided by the installation at one of the pits of Messrs. Glass, Houghton and Castleford Collieries, Limited, Castleford. The electrical equipment for this installation was supplied by Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, the contract including power and lighting transformers and high-tension oil-immersed switchgear, as well as contactor control gear operated from remote push-button cubicles, and over 40 motors, with a total output of nearly 300 h.p.

Among the special claims made for this method of centralised control is that it possesses the advantage of enabling the control gear to be installed in a separate switch house away from the washery, so that trouble from dust and dirt is eliminated. Open-type contactors can, therefore, be used, thus facilitating inspection and maintenance. Groups of motors can also be controlled from one position, so that the starting and running of the plant are simplified. Further, it is only necessary to provide main power cables to the contactor board, smaller cables being run thence to the motors and multi-core cables to the push-button stations.

At Castleford, the 3,300-volt incoming alternating-current supply for the washery is controlled by two oil-immersed industrial-type circuit breakers of the horizontal draw-out pattern, from which feeders are taken to a 500-kVA power transformer and a 75-kVA transformer for the 110-volt lighting circuits. The power transformer steps down the voltage to 440 volts and supplies a four-unit oil-immersed industrial switchboard, which feeds three contactor switchboards. These control the motors for the washery, wagon tippler and coal-handling equipment, respectively. In view of the prevalence of dust and dirt, all the washery motors are of the General Electric Company's totally-enclosed fan-cooled design, in which cooling is assisted by an external fan that forces air over the shell of the machine. With this form of construction, it is claimed, it is impossible for dust, dirt or moisture to gain access to the interior, while the forced ventilation enables the overall size of the motor to be reduced appreciably as compared with ordinary totally-enclosed machines. The outputs of the motors range from ¼ h.p. to 20 h.p., and, with the exception of three slip-ring machines, they are of the squirrel-cage type. One of the latter, which has an output of 7½ h.p., is visible in the foreground of Fig. 1, which is a general view of the washing plant. Fig. 2 is another view of the plant, showing the position of three more motors. The general appearance of the pump house will be clear from Fig. 3. It contains motors ranging from 3 h.p. to 12½ h.p., and one of the push-button control cubicles, which are referred to below, is visible on the left of the illustration.

All the motors are controlled by contactor starters, which are mounted on a flat-back switchboard, as shown in Fig. 4. This is installed in a separate switch house away from the coal-washing plant. Each squirrel-cage motor is started by switching direct to the line, the control equipment comprising a triple-pole contactor with adjustable thermal overload trips, a triple-pole isolator, and three high rupturing-capacity fuses. These are enclosed in porcelain shields and are rated at 25,000 kVA. The function of these fuses is to safeguard the apparatus against damage under short-circuit conditions. An ammeter is also provided for each machine. The control equipments are mounted in groups of three, which are arranged one above the other on the switchboard panels. Contactor-type rotor starters are used for the control of the three slip-ring motors, each starting equipment being mounted on a separate panel of the switchboard. The apparatus includes a triple-pole isolator and triple-pole stator contactor, with overload release of the solenoid pattern, two 75-ampere rotor contactors for cutting out the rotor starting resistance in steps, three high rupturing-capacity fuses, and an ammeter. The rate of acceleration of the motors is governed by a clockwork timing mechanism, which controls the operation of the rotor contactors. Open-type contactors are used throughout.

All the motor-starting apparatus is remote-controlled from six push-button cubicles, which are situated at convenient positions in the washery. One of these cubicles is illustrated in Fig. 5. Each controls a number of motors and comprises "stop" and "start" push-buttons, with a pilot indicating lamp for each motor and an emergency "stop" button. The cubicles are of sheet-steel construction and are dust-proof. They are arranged for floor mounting. Access is obtainable from the front, and, as will be clear from Fig. 5, all the equipment is mounted on a hinged panel.

COAL-WASHING PLANT CONTROL.

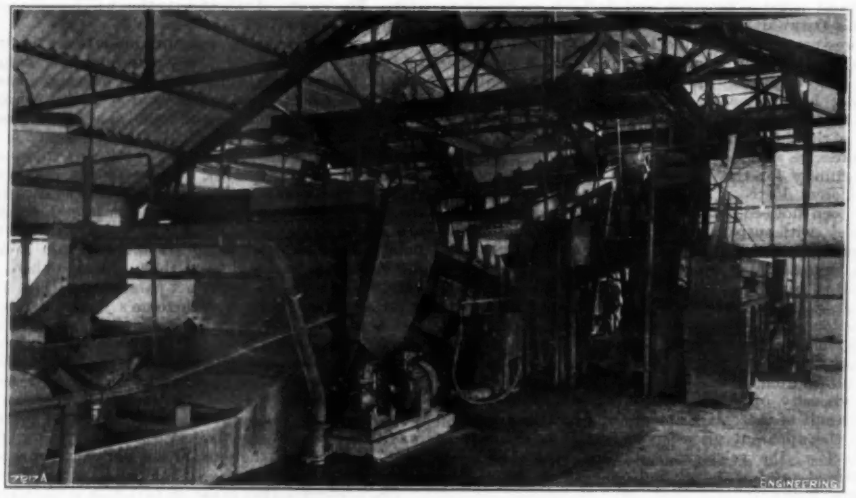


Fig. 1. General View of Plant.

Fig. 2. Coal-Washing Machine and Driving Motors.

Fig. 3. Interior of Pump House.

COAL-WASHING PLANT CONTROL.

(*For Description, see Opposite Page.*)

FIG. 4. MAIN CONTACTOR SWITCHBOARD.

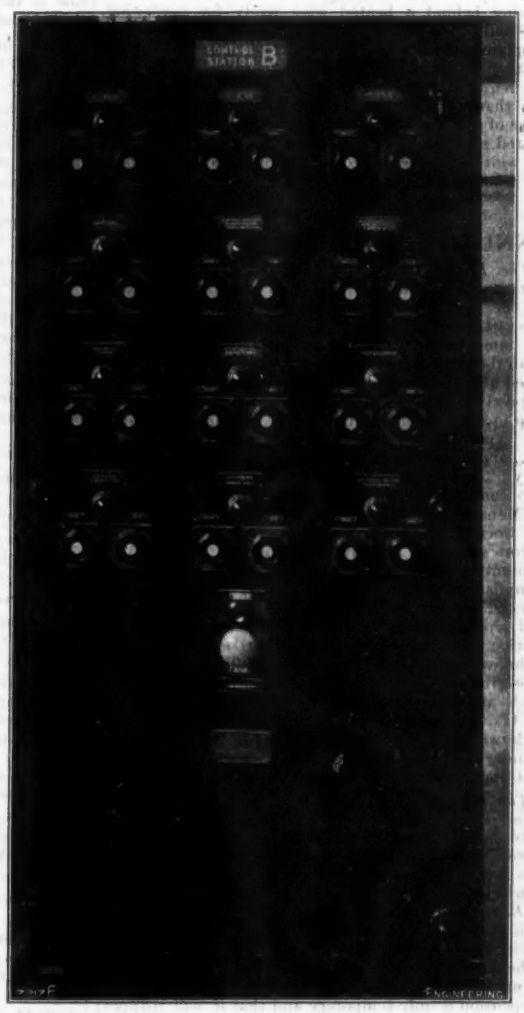


FIG. 5. PUSH-BUTTON CONTROL CUBICLE.

THE HEAT TREATMENT OF STEEL BY HIGH-FREQUENCY CURRENTS.

IN an original communication on "Heat Treatment of Steel by High-Frequency Currents," which was published in the February issue of the *Journal of the Institution of Electrical Engineers*, Messrs. G. Babat and M. Losinsky discussed some of the problems arising from the use of high-frequency currents in processes involving peripheral heating and especially surface hardening. The method has the advantages that, as the heating only extends to a small percentage of the volume of the metal being treated, defects, such as warping, which are produced by the usual heating and hardening processes, are almost completely avoided. The equipment can deal with large quantities of metal in a short time, as the heating of the peripheral layer of the specimen to the hardening temperature only takes a few seconds. The cost is low and the working conditions are more equable than with other methods. The surface hardening of these layers requires an input of from 100 watts to 1,000 watts per square centimetre. The use of frequencies of the order of 10^5 cycles per second is necessary, therefore, as only in this way can sufficient power be obtained with comparatively small values of magnetic field. Since with these frequencies the depth of penetration is small compared with the dimensions of the specimen, both it and the heating coil can be considered to have zero magnetic permeability so that the lines of magnetic force follow, but do not cross, their surfaces.

It is important that the heating coil should be shaped so as to induce eddy currents only in the local surface areas which are to be heated. The configuration of the hardened layer depends upon the location and dimensions of the coil and the part which is being heated; and it can be given a uniform thickness by making the height of the coil equal to the height of the specimen less twice the distance between the coil and the specimen. Usually, the distance from coil to specimen is from 2 mm. to 5 mm. and in order, therefore, to obtain a uniform thickness of hardened layer on the outer surface of a cylindrical specimen, the coil should be 5 mm. to 10 mm. shorter than the specimen. The power absorbed by the specimen first increases with the temperature and then suddenly diminishes when the steel passes over to its non-magnetic modification. This peculiarity of the procedure of heating steel parts by eddy currents is of great importance, as it ensures a high grade of hardening and does not permit surface overheating. If the surface layer is heated for hardening purposes by autogen burners, the power input to the surface remains constant throughout the heating period. It is, therefore, very difficult to avoid overheating the peripheral layer. On the other hand, when eddy-current heating is employed above the point of magnetic transmutation, heat is conducted into the interior of the specimen and the rate of rise of temperature at the surface diminishes.

To obtain hardened layers about 1 mm. thick, it is necessary to employ the thermal-capacity type of heating process, with heating times of the order of 1 second and high power input. For thicknesses exceeding 5 mm., heating may be accomplished in a short time, if a low frequency is employed, but a higher power input is then necessary. On the other hand, a high frequency means lower power input and a longer heating period. For a given power input the area which can be treated in a given time is smaller with low-frequency than with high-frequency heating. The area which can be hardened in 1 second is determined by the power of the oscillator and not by its frequency. For the great majority of machinery parts, 10^5 cycles to 10^6 cycles per second may be taken as the optimum frequency range, while hardening to a thickness of 2 mm. to 3 mm. requires 800 watts to 1,000 watts per square centimetre of the surface treated. When a steel part is rapidly heated in a non-uniform field, the power absorbed increases with the temperature up to 750 deg. C., and any slight initial non-uniformity of power distribution on the surface of the specimen also tends to increase. Increasing the power absorbed raises the temperature, with the result that there is a further increase of power input to the areas heated to a higher temperature. Near the Curie point the power input decreases with a rise of temperature, so that the temperature distribution on the surface of the specimen becomes more uniform, as areas heated to a higher temperature absorb less power than those heated to a lower temperature. Similarly, the configuration of the hardened layer depends on its thickness. When this is small compared with its height, the smoothing effect of thermal conduction along the layer is absent, and in order to obtain a layer of uniform thickness the shape of the heating coil must be selected very carefully. Moreover, these layers require high values of power input per unit area of surface. The thicker the layer to be hardened, the more uniform is the temperature distribution owing to thermal conduction, and the less is the configuration of the layer affected by the shape of the heating coil.

For the heating coil to have a high efficiency, its breadth must be 10 times to 20 times less than its length. Single-turn coils are preferable, therefore, for hardening cylindrical parts, where the height of the layer to be hardened is less than the diameter of the specimen. On the other hand, when heating such things as taps and reamers, where the height of the layer to be heated is two times to three times the diameter, it is better to use multi-turn coils. It is not advisable to apply inductive heating to cylindrical and

prismatic bodies, of which the length is ten or more times the diameter. Instead, the specimen should be connected to the terminals of a high-frequency transformer. For specimens where there is a large surface area to be hardened, as in rolling mills, the heating coil may be moved along the surface of the work, leaving behind a heated zone ready for hardening. The coil is followed by the arrangement employed for supplying the cooling liquid. The more slowly the heating proceeds the wider must be the coil to give the required speed. The efficiency of this method is less than that of the simultaneous method, because some of the heat is wasted by lateral radiation from the heated zone, and in order to obtain satisfactory results the width of the heated zone must not be less than about ten times the thickness of the layer to be hardened.

ANNUALS AND REFERENCE BOOKS.

The British Corporation Register Book.—The 1940 edition of its *Register of Ships* has recently been issued by the British Corporation Register of Shipping and Aircraft, 14, Blythswood-square, Glasgow, C.2. As its name implies, the volume contains data relating to all the ships classed in this Registry, the vessels being listed alphabetically and also under the names of their respective owners. The particulars given for each ship include her main dimensions, her port of registry, her type, rig, tonnage figures, number of bulkheads, etc., and information concerning her propelling machinery. As has previously been the case, the volume also contains lists of the members of the Committee of Management and of the Technical Committee of the Society, of the Liverpool Committee, and of surveyors stationed at ports at home and abroad. The Committee of Management, which is responsible for the compilation of the Register Book, is composed of owners, builders and designers of ships, marine engineers, and representatives of the aircraft industry, of underwriting associations, and of various engineering and technical institutions. The Register Book is issued to subscribers only, the terms of subscription, to individuals and firms, being 3*l.* 3*s.* for the first copy and 1*l.* 11*s.* 6*d.* for each additional copy. In the case of underwriting associations and marine-insurance companies, the terms of subscription are 4*l.* 4*s.* for the first copy, and 2*l.* 2*s.* for each additional copy.

The Blue Book, the Electrical Trades Directory and Handbook.—The fifty-eighth edition of *The Blue Book*, published by Messrs. Benn Brothers, Limited, Bouverie House, Fleet-street, E.C.4, at the price of 25*s.* net, this year incorporates the title of this company's other electrical reference book, *The Annual Tables of Electricity Undertakings*. As, however, this publication appears to be absent from the volume sent for review, we presume that the stern hand of war, either in the guise of the censorship or in some other form, has fallen upon it. We hope, however, that its suspension is only temporary and that it will reappear in the near future, since it contains a great deal of useful data regarding a growing industry. About the *Blue Book* itself, it is difficult to say anything that has not been said before. The editorial arrangement is in four main sections—commercial and technical data (including lists of officers of trade and professional organisations), an alphabetical list covering firms, persons and societies in the electrical and engineering industries, a geographical section, and a classified section. There are also pages of trade names and telegraphic addresses. Quick reference is provided by tabled guide cards. The volume tends to grow in size and it is, therefore, a matter for consideration whether some of the technical information given in the handbook section might not be omitted, especially as it is more fully obtainable elsewhere. Great care has been taken in the compilation of the Directory section, though we have come across a few errors, and it should prove no less useful in the future than it has done in the past.

Almanacs.—Messrs. Stewarts and Lloyds, Limited, Winchester House, Old Broad-street, London, E.C.2, have sent us a monthly-card desk calendar in a handsome frame.—A neat weekly turn-over desk diary and engagements pad has come to us from Messrs. Stothert and Pitt, Limited, Bath.—Messrs. Vosper, Limited, Broad-street, Portsmouth, have sent us a wall calendar for 1940.—Messrs. Ransome and Marles Bearing Company, Limited, Newark-on-Trent, have sent us a daily tear-off and monthly tear-off calendar combined.—A wall calendar has been addressed to us by Messrs. James Light and Son, Limited, Mona Lodge, Epsom, Surrey.

American Society for Testing Materials.—The 43rd annual meeting of the American Society for Testing Materials will take place from June 24 to 28, at Atlantic City, New Jersey, U.S.A. The proceedings will include a symposium on tensile testing.

TENDERS.

We have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Wall Plugs and Ceiling Roses. Indian Stores Department, Electrical Branch, New Delhi.; April 4. (T. 16,398/40.)

Electrical Plant and Boilers for the Bezwada Thermal Scheme, comprising a 3,000-kW turbo-alternator set; a 33,000-lb. per hour boiler and accessories, indoor and outdoor switchgear, and extension pipework for the cooling pond; March 27. Also a 1,500-kVA, 3·3/11-33-kV power transformer and arc-suppression coil; April 9. Government of Madras Electricity Department, Chepauk, Madras. (T. 16,090/40.)

Woodworking Machinery, comprising a motor-driven 30-in. band sand, motor-driven sharpener, and ¼-in. portable electric drilling machine, and *Spray-Painting Outfit* with accessories, for Valkenberg Mental Hospital, Cape Province. Union Tender and Supplies Board, Pretoria; March 14. (T. 16,293/40.)

Switchgear, indoor, totally-enclosed, iron-clad, compound-filled, single 'bus-bar, unit-type, suitable for controlling 6,000-volt, three-phase, three-wire, 50-cycle circuits. State Electricity Commission of Victoria, Melbourne, Australia; April 2. (T. 16,495/40.)

Asphalt-Mixing and Drying Plant, suitable for hot or cold mix. Administration of the City of Pietermaritzburg, South Africa; March 15. (T. 16,571/40.)

Grinding Wheels.—South African Railways and Harbours, Johannesburg; April 18. (T. 16,631/40.)

Wardrobe Lockers, steel. Union Tender and Supplies Board, Pretoria: April 4. (T. 16,635/40.)

Hardware and other materials for the South African Police. Union Tender and Supplies Board, Pretoria; March 28. (T. 16,636/40.)

Weighing and Measuring Equipment, comprising a 50-lb. gunmetal outdoor beam scale, sets of standard troy, metric, avoirdupois and metric-carat weights, various standard measures of capacity, one only 100-ft. standard, steel tape measure, and 45 wrought-steel, hand-operated sealing pliers. Union Tender and Supplies Board, Pretoria; April 4. (T. 16,638/40.)

Transformers, two, 66,000-volt, and one voltage and phase-angle regulator. State Electricity Commission of Victoria, Melbourne, Australia; April 30. (T. 16,494/40.)

Steel Plates in quantity. South African Railways and Harbours, Johannesburg: April 1. (T. 16,630/40.)

Electric Passenger Lifts. With reference to the call for tenders for electric passenger lifts for Government Buildings, Cape Town, noted on page 224, *ante*, we now learn that the Union Tender and Supplies Board, Pretoria, has postponed the closing date from March 14 to April 11. (T. 16,300/40.)

BOOKS RECEIVED.

Annuaire pour l'An 1940. Avec des Notices Scientifiques. Edited by Le Bureau des Longitudes. 55, quai des Grands-Augustins, Paris (VIe.): Gauthier-Villars. [Price 25 francs.]

United States National Bureau of Standards. Building Materials and Structures. Report BMS25. *Structural Properties of Conventional Wood-Constructions for Walls, Partitions, Floors and Roofs.* By G. E. Heck. [Price 15 cents.] Report BMS32. *Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association.* By H. L. Whittemore, A. H. Stang and D. E. Parsons. [Price 10 cents.] Washington: Superintendent of Documents.

United States Bureau of Labor Statistics. Serial No. R. 1011. *Industrial Injuries in the United States During 1938.* Washington: Superintendent of Documents.

University of Minnesota. Engineering Experiment Station. Bulletin No. 15. *Laboratory Studies of Asphalt Cements.* By Professor F. C. Lang and T. W. Thomas. Minneapolis, Minn., U.S.A.: The Director, Engineering Experiment Station, University of Minnesota.

Department of Scientific and Industrial Research. Report of the Food Investigation Board for the Year 1938. London: H.M. Stationery Office. [Price 4*s.* 6*d.* net.]

The Association of Engineering and Shipbuilding Draughtsmen. Principles of Electric Arc Welding. By I. H. Child. 1, Links-road, Epsom, Surrey: The Draughtsman Publishing Co., Ltd. [Price 2*s.* net.]

The Corrosion of Iron and Steel. Being a General Account of the Work of the Corrosion Committee of the Iron and Steel Institute and the British Iron and Steel Federation. By Dr. J. C. Hudson. London: Chapman and Hall, Ltd. [Price 18*s.* net.]

PERSONAL.

Mr. A. Vines, who was appointed works manager of Messrs. Evershed and Vignoles, Limited, Acton-lane Works, Chiswick, London, W.4, when the company was first formed in 1895 and has been joint managing director since 1909, has now retired from this position. He still, however, retains a seat on the board of directors.

Messrs. Bakelite, Limited, Brackley Lodge, Brackley, Northants, have acquired the works and business of Messrs. Warerite, Limited, Ware, Herts, who have been engaged in the manufacture of synthetic-resin, laminated-sheet materials. The acquisition, we are informed, will assist Messrs. Bakelite to meet the growing demands for laminated Bakelite.

Mr. P. T. Eckersley, M.P., has been appointed Parliamentary private secretary to Major G. Lloyd George, M.P., Parliamentary Secretary to the Board of Trade.

Messrs. Sulzer Bros. (London), Limited, 31, Bedford-square, London, W.C.1, inform us that Messrs. Sulzer Frères, S.A., of Winterthur, Switzerland, have recently disposed of their Ludwigshafen Works.

Messrs. The Brush Electrical Engineering Company, Limited, Loughborough, owing to the expansion of their sales organisation in the Manchester area, and, in order to provide better services to their clients, have opened new offices at Daimler House, Wilmslow-road, Rusholme, Manchester, 14. The offices at Haworth Buildings, Cross-street, Manchester, have been vacated.

The secretariat of the directing commission of the Belgian publication, *Annales des Travaux Publics*, has removed its offices from 3, Place de Louvain, to 15, Rue des Cultes, Brussels.

NOTES FROM THE NORTH.

Glasgow, Wednesday.

Scottish Steel Trade.—The urgent demand for steel material of all descriptions continues. All plant is running to capacity and the present high rate of production has never before been equalled. The shipyards are consuming an enormous tonnage of steel and many engineering establishments are pressing for supplies for work of national importance. Boiler plates, ship plates, sections, etc., are all going rapidly into consumption. The demand for light material is also heavy and the makers of black-steel sheets have orders on hand for a considerable tonnage. The current prices of steel are as follows:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.* per ton; sections, 12*l.* 8*s.* per ton; medium plates (under ⅜ in. thick), weighing 6 lb. or more per square foot, 14*l.* per ton, and weighing under 6 lb. but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in 4-ton lots, 20*l.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—Conditions in the malleable-iron trade of the West of Scotland have varied little over the week and, with satisfactory order books, plant is fully occupied. The re-rollers of steel bars are exceptionally busy and buyers are pressing for deliveries. The supply of semies is fairly good at the moment but the requirements of the industry are very large. The following are to-day's prices:—Crown bars, 12*l.* 17*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton, and No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars (tested), in 4-ton lots, 12*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—The output of Scottish pig-iron is being fully maintained and, so great is the pressure from the steelworks, that every ton produced is rapidly cleared. Deliveries of hematite and basic iron are in urgent request but foundry grades of iron are still somewhat slow. The current market quotations are as follows:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

Plans of Abandoned Mines.—The plans of abandoned mines, totalling upwards of 50,000 sheets, preserved in the Mines Department and removed from London for safety on the outbreak of war, have now been housed in an office in Buxton. All applications to inspect the plans should be addressed to The Surveyor, Mining Record Office, Oakleigh, Park-road, Buxton. Plans can be inspected at this office on weekdays between 10 a.m. and 12 noon and 2 p.m. and 4 p.m. (Saturdays from 10 a.m. to 12 noon), or, by prior arrangement, they can be forwarded for inspection at the office of any Divisional Inspector of Mines or at the Mines Department, Mill House, 87-89, Shaftesbury-avenue, London, W.1.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Demand remained very active in both the home and overseas sections of the Welsh steam coal market. The amount of new business that could be concluded, however, was still very limited. Collieries' present outputs were being steadily absorbed by contract deliveries, while most producers still had arrears of shipment to make good. Salesmen, as a rule, held well-filled order books over some months ahead. Consequently, any odd parcels which became available on the market were eagerly taken up and the general tone was very firm. Duff coals remained the outstanding feature of the market. Supplies of these sorts were extremely scarce, and sellers, generally, had disposed of their potential supplies for several months ahead. Sized and large descriptions were only very sparingly available, while smalls remained limited. The demand for cokes was actively maintained, but supplies were practically unobtainable. Patent fuel continued in good demand.

The Iron and Steel Trades.—Active conditions were again in evidence in the iron and steel and allied trades of South Wales and Monmouthsire during the past week. Most works were engaged almost to full capacity, and the demand for finished products was maintained. Order books were well filled.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—With pressure for the delivery of most commodities unabated, a very firm tone continues to exist on the market, and rigid operation of the licensing control is still necessary to ensure the distribution of material in a manner that provides for essential needs. There is a substantial inquiry for tonnage for ordinary industrial purposes and the usual buyers are anxious to negotiate for early and forward supplies. Priority delivery claims, however, continue to restrict the general commercial business. The unprecedented output of iron and steel continues to expand.

Cleveland Iron Trade.—Although the supplies of foundry iron are adequate for current needs, consumers are unable to obtain deliveries on a scale which is sufficient for the accumulation of stocks. North East Coast ironfounders are making extensive use of Midland iron and are experiencing little inconvenience by the scarcity of Cleveland pig, the output of which is still suspended. The intermittent make of a substitute for the recognised brands of Tees-side foundry pig is promptly taken up. Merchants are handling very little local iron. The fixed prices of Cleveland pig remain at the level of No. 3 quality at 111*s.*, delivered within the Tees-side zone.

Hematite.—The producers of East Coast hematite are continuing to keep pace with requirements for consumption, but have little saleable tonnage. The heavy make is not quite equal to the demands for delivery and the tonnage stored at the blast-furnaces has shrunk to as low a level as is considered advisable. Contract obligations are extensive and the requirements of makers' own consuming departments are large and increasing. Stabilised quotations remain on the basis of No. 1 grade of hematite at 127*s.* 6*d.*, delivered to North of England areas.

Basic Iron.—The nominal price of basic iron is 104*s.* 6*d.* The whole of the Tees-side output continues to pass into direct use at makers' adjoining steelworks.

Foreign Ore.—The import of foreign ore is steadily maintained, and consumers have satisfactory stocks.

Blast-Furnace Coke.—The light business passing in Durham blast-furnace coke is due to the circumstance that holders have substantial contracts to execute and local users are well covered; deliveries are regular and ample. The market values are ruled by good medium qualities at 31*s.* 8*d.* at the ovens.

Manufactured Iron and Steel.—The increased make of semi-finished iron and steel and the imports of Continental semi-products, are supplying re-rollers with material that enables them to keep the mills actively employed. Plant making light iron castings is operating only moderately, but other branches of the finished industries are busy. Sheetmakers have full order books and manufacturers of shipbuilding requisites have almost as much work on hand as they can handle.

Scrap.—While deliveries of iron and steel scrap have improved, complaints of shortage are still heard and any available parcels are quickly taken up.

THE ALFEITE ARSENAL, PORTUGAL.—It is stated in the *Journal de la Marine Marchande* that the first ship built at the new Alfeite Arsenal, Portugal, is shortly to be launched. The vessel, which is to be employed on hydrographic work, has a tonnage of 1,140 and is 215 ft. 6 in. in length.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—A high level of activity is being maintained by steelmakers, and large batteries of furnaces, many put down during the past few months, are turning out record tonnages of all types of materials. Scrap merchants are having a busy time; all available supplies of steel or cast-iron scrap are quickly sold, but little difficulty would be experienced in disposing of larger tonnages. Sheffield Corporation has sanctioned the sale of 80 tons of old tram rails at 102*s.* 6*d.* per ton to a Sheffield scrap firm. There is a strong demand for alloys used in the manufacture of high-class steels. Active conditions prevail in the heavy machinery and heavy engineering branches. The recent strong demand for steelworks and ironworks machinery and related equipment has been maintained; not only is new plant in good request, but a run has developed on reconditioned machinery. Owing to the large stocks carried by well-known firms dealing in second-hand machinery, little difficulty is experienced in satisfying the needs of customers. Firms specialising in the production of rolling mills, hydraulic presses, steam hammers, and other equipment have good order books. Orders are numerous, and not only on home account; there is a better call from abroad. Coal-mining plant is in demand, and there is a stronger call for steel props and girders. Other lines in request are coal-crushing and screening machines, steel tubs, winding gear, and coal-cutting machines. Makers of electrical plant and steel are extremely active, power plant being on order on both home and overseas account. Small electric traction motors find a ready market, while electric motors for industrial and agricultural purposes are in demand. Sheffield Corporation has received consent from the Electricity Commissioners to use the anticipated surplus from the undertaking for the conversion of the old tramway generating station at Kelham Island into main stores for heavy equipment, repair shops, and a garage. The season in agricultural machinery and implements is now in full swing, and local makers are doing a brisk trade. The demand for all types of tools has been maintained; there is a record call for engineers' small tools.

South Yorkshire Coal Trade.—Industrial coal is again moving freely, and consuming works are now experiencing little difficulty in obtaining ample supplies. Electricity undertakings are taking increased tonnages; Sheffield Corporation are to enter into contracts for an additional supply of 1,050 tons per week. Railway companies are also good customers, and house-coal merchants are steadily wiping off arrears of contracts. The export position has undergone little change.

WIRING RULES OF THE INSTITUTION OF ELECTRICAL ENGINEERS.—A supplement to the eleventh edition of the Regulations of the Institution of Electrical Engineers for the Electrical Equipment of Buildings was recently approved by the Council, and is obtainable free of charge on application to the Institution. Certain definitions have been amended, alterations have been made to regulations on the control of electric heating appliances, and new clauses have been added on the control of non-luminous or panel electric heating and in regard to the cross-sectional area of earth continuity conductors.

THE "JOURNAL OF COMMERCE" ANNUAL REVIEW.—The 1940 issue of the annual review of shipping, shipbuilding and marine-engineering events and progress, published by *The Journal of Commerce and Shipping Telegraph*, 17, James-street, Liverpool, 2, contains, in addition to the customary general surveys, a number of signed articles on individual topics of technical interest. For example, freight rates are discussed by Mr. Robertson F. Gibb, president of the Chamber of Shipping, and British port developments by Dr. Brysson Cunningham, M.Inst.C.E. There is also a useful chronology of the war at sea, from August 22 to December 31, 1939, contributed by Mr. Frank C. Bowen.

AMPHIBIAN TRACTOR.—Illustrations and a brief description of an amphibian tractor, intended for work in flooded areas, are given in a recent issue of the American journal *Steel*. The vehicle, which is known as the Alligator and has been built by Mr. Donald Roebling, Clearwater, Florida, bears some resemblance to a light military tank and is propelled, both on land and in the water, by means of curved cleats, 6 in. high, mounted on two endless chains, one on each side of the body. It is stated that the maximum speed on land is 25 m.p.h. and, in the water, 8·6 m.p.h. The body, or hull, which is made of Duralumin, is 20 ft. long, and the draught, when unloaded, is 3 ft. On land, the clearance under the body is 22 in. The propelling engine employed is a Mercury V8 of 95 horse-power. Two 50-gallon fuel tanks are provided. Two rings are fitted at the rear of the tractor for towing purposes on land or on the water. The tractor, it is stated, accommodates 40 standing passengers or can carry a cargo of 7,000 lb.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

PHYSICAL SOCIETY.—To-day, 5 p.m., Birkbeck College, Bream's Buildings, Chancery-lane, W.C.2. (i) Demonstration of Flocculation in Pigment Systems, by Miss D. L. Tilleard. (ii) "The Colour of Pigment Mixtures," by Dr. D. R. Duncan. (iii) "The Use of Uniform Chromaticity Scales," by Mr. J. G. Holmes. (iv) "The Characteristics of Protanomalous Vision," by Mr. W. M. McKeon and Dr. W. D. Wright.

ROYAL INSTITUTION.—To-night, 5 p.m., 21, Albemarle-street, W.1. "Experiments from the Researches of Sir James Dewar," by Sir William Bragg. Wednesday, March 13, 5.15 p.m., "X-Ray Optics," by Prof. W. L. Bragg.

INSTITUTION OF CHEMICAL ENGINEERS.—To-night, 5.15 p.m., The Geological Society's Rooms, Burlington House, Piccadilly, W.1. (i) "Further Experiments on the Evaporation of Water from Saturated Surfaces," by Dr. W. R. Powell. (ii) "Heat Transmission in Evaporative Condensers," by Dr. A. K. G. Thomson.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—To-night, 6 p.m., The Mining Institute, Newcastle-upon-Tyne. "Mean Pitch Determination of Variable Pitch Propeller," by Dr. E. V. Telfer. *Student Section:* Wednesday, March 13, 6.45 p.m., Bolbec Hall, Newcastle-upon-Tyne, 1. "Governing and Regulating of Land Turbines," by Mr. P. J. Daglish.

INSTITUTION OF ELECTRICAL ENGINEERS.—Monday, March 11, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Joint Meeting with THE INSTITUTION OF CIVIL ENGINEERS and THE INSTITUTION OF MECHANICAL ENGINEERS. Discussion on "Emergency Repairs, with Special Reference to Welding." *North-Eastern Centre:* Monday, March 11, 6.15 p.m., Newe House, Pilgrim-street, Newcastle-upon-Tyne. "Oil-less Metalclad Switchgear for Medium-Voltage A.C. Circuits," by Messrs. H. E. Cox and L. Drucquer. *Transmission Section:* Wednesday, March 13, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. "Electric Cables and Fire Risks," by Mr. S. W. Melsom. *Meter and Instrument Section:* Friday, March 15, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussions on (i) "Cathode-Ray and Duddell-Type Oscillators," to be opened by Professor J. T. MacGregor-Morris. (ii) "The Practical Limits of Error in A.C. House Service Meters and in Sub-Standard Watt Meters," to be opened by Mr. A. J. Pitt.

INSTITUTION OF THE RUBBER INDUSTRY.—*London and District Section:* Monday, March 11, 7.15 p.m., Northumberland Rooms, Northumberland-avenue, W.C.2. Joint Meeting with the *Plastics Group*, SOCIETY OF CHEMICAL INDUSTRY. "The Chemist and Electrical Insulation," by Mr. L. Massey.

WOLVERHAMPTON AND DISTRICT ENGINEERING SOCIETY.—Monday, March 11, 7.30 p.m., Victoria Hotel, Wolverhampton. Lecture: "Ventilating and Air Conditioning," by Mr. Edwin Leach.

IRON AND STEEL INSTITUTE.—Tuesday, March 12, 6.45 p.m., Midland Hotel, Birmingham. (i) "'Strain-Age-Hardening' of Mild Steel," by Messrs. A. C. Edwards, H. N. Jones and B. Walters. (ii) "Strain-Ageing of Dead-Mild Steel Strip Used in the Pressing of Automobile Bodies and Accessories," by Dr. J. W. Rodgers and Mr. H. A. Wainwright.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Coventry Centre:* Tuesday, March 12, 7 p.m., King's Head Hotel, Coventry. "Modern Applications of Cast Iron in Automobile Construction," by Messrs. E. C. Toghill and R. V. Dowie. *Luton Centre:* Tuesday, March 12, 7.30 p.m., George Hotel, Luton. "A Few Odd Notes on Engines," by Mr. A. Taub. *North-Western Centre:* Wednesday, March 13, 7.15 p.m., Engineers' Club, Manchester. "Alternative Fuels for C.I. Engines," by Mr. W. Allen.

NEWCOMEN SOCIETY.—Wednesday, March 13, 2.30 p.m., The Institution of Civil Engineers, Great George-street, S.W.1. (i) "Electrical Invention and Re-Invention," by Mr. W. T. O'Dea. (ii) "Amédée Bollée," by Mr. J. R. Nichols.

INSTITUTION OF ENGINEERS-IN-CHARGE.—Wednesday, March 13, 7 p.m., St. Bride Institute, Fleet-street, E.C.4. "Paints and Varnishes," by Mr. A. E. Robinson.

INSTITUTION OF MINING AND METALLURGY.—Thursday, March 14, 4.30 p.m., Geological Society's Rooms, Burlington House, Piccadilly, W.1. "Mining and Milling Tin-Tungsten Ore at Mawchi Mine, Burma," by Messrs. J. E. Denyer and K. C. G. Heath.

INSTITUTE OF FUEL.—Thursday, March 14, 6 p.m., Connaught Rooms, Great Queen-street, W.C.2. "Regenerative Feed Heating in Industrial Power Plants," by Mr. A. F. Webber.

INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 15, 6 p.m., Storey's-gate, Westminster, S.W.1. General Meeting. Thomas Lowe Gray Lecture: "Fifty Years of Marine Engineering," by Prof. A. L. Mellanby.

MECHANICAL ENGINEERING IN POWER STATIONS.

(*For Description, see Page* 263.)

Fig. 1. Engine Room at Wood-lane Station, London, in 1902.

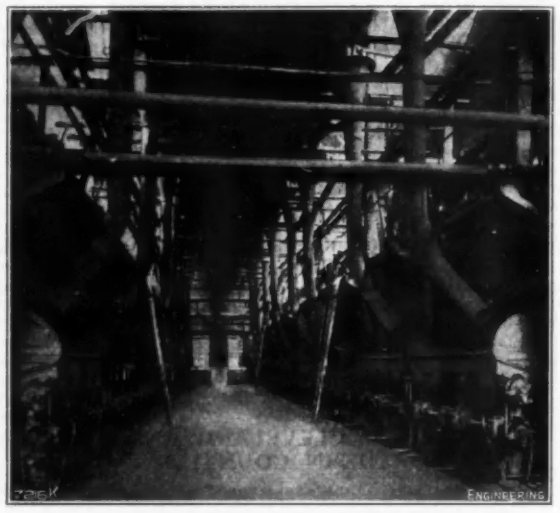


Fig. 2. Boiler House at Wood-lane Station, London, in 1902.

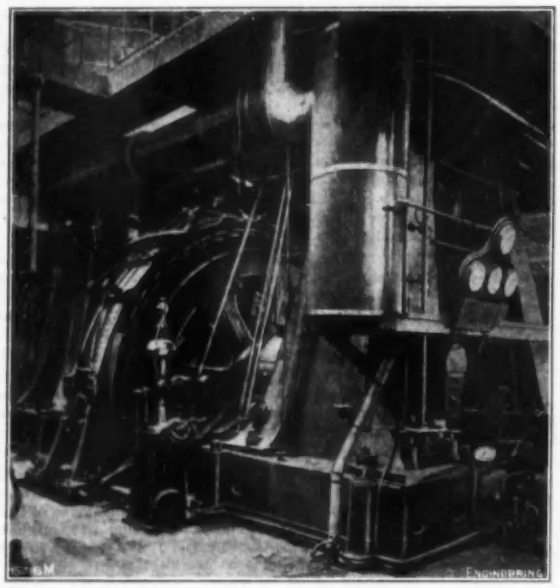


Fig. 3. 2,500-I.H.P. Yates and Thom Engines and 1,500-KW Generators at Stuart-street Station, Manchester, in 1902.

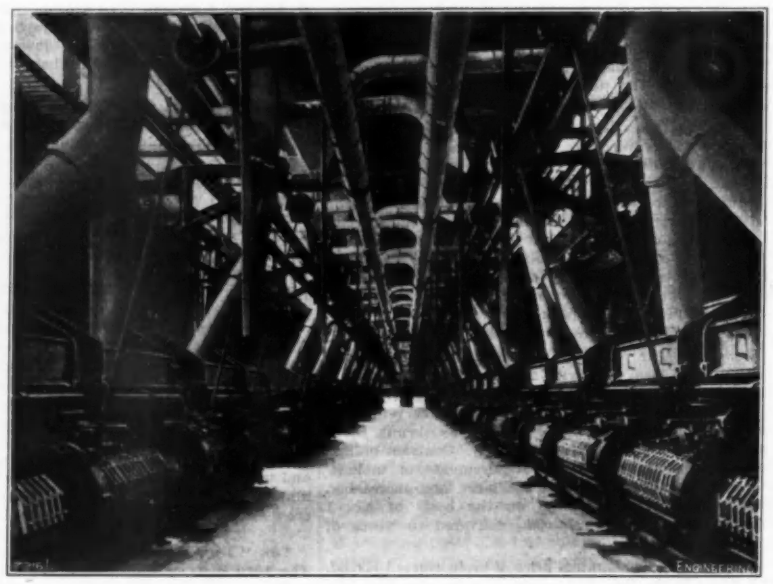


Fig. 4. Boiler House at Stuart-street Station, Manchester, in 1902.

BRITISH STANDARD SPECIFICATIONS.

The following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 2*d.* including postage.

Transmission and Distribution Voltages.—Since the publication, in March, 1932, of the third revision of specification No. 77, dealing with standard voltages for transmission and distribution alternating-current systems, there have been considerable changes in practice. Accordingly, the fourth revision of the specification, now published, takes account of the progress made. The chief change is the substitution of two standard voltages, namely, "system voltage" and "declared voltage," for the four voltages included in the 1932 edition. System voltage is defined as the voltage between lines for which the system is designed and installed, while the declared voltage is the voltage, at the consumers' terminals, declared by the undertaker. In the interests of general standardisation, the specification is not now confined to new systems, and a revised list of standard voltages is given. [Price 1*s.* net, or 1*s.* 2*d.* post free.]

Gauges for A.R.P. Lighting.—One of the difficulties in complying with the provisions of the various regulations and specifications in connection with A.R.P. lighting is that the illumination values are expressed in foot-candles. The measurement of these values presents no difficulties in properly-equipped laboratories, but it is definitely a problem to evaluate illumination on the site, particularly when the level of lighting is of the low order imposed by A.R.P. restrictions. For many purposes it is not required that quantitative measurements should be made, but merely that tests be carried out to ascertain whether the illumination is in excess of, or less than, the prescribed value. With this in view, gauges for checking low values of illumination have been developed and a specification, BS ARP No. 30, dealing with them has been published. The nominal values of illumination for which gauges are prescribed are 0·0002, 0·002, 0·02, and 0·2 foot-candle, and means may be provided for enabling more than one of these values to be gauged with the same instrument. The specification aims at ensuring the necessary accuracy combined with portability, but leaves the manufacturer free to develop his own design. An appendix giving notes on the essential parts of the gauges, and on their use, is included. [Price 2*d.* net, or 3*d.* post free.]

Nomenclature of Hardwoods.—For some time past the confusion of names given to various timbers has been a serious matter for many persons engaged in the marketing of material for the woodworking industries. This confusion has increased considerably of late years with the introduction of many additional species of timber as an outcome of the development of Empire forest resources. The need for a standard nomenclature of species of timber was felt and, in 1935, a publication dealing with 74 species of softwoods was issued. This has now been followed by a standard nomenclature of hardwoods (No. 881-1939), in which 240 species are catalogued. The list includes all the hardwoods of actual or potential commercial importance in this country and has been compiled by representatives of Government departments and scientific and industrial organisations, thus ensuring that its application will be general. The guiding principle upon which the nomenclature has been based was to establish a single standard name for each timber, and to restrict the name to that one timber. [Price 3*s.* 6*d.* net, or 3*s.* 8*d.* post free.]

ENGINEERING.

Offices for Publication and Advertisements, 35 & 36, Bedford Street, Strand, London, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS { "ENGINEERING," LESQUARE LONDON.

TELEPHONE NUMBER—TEMPLE BAR 3663 (2 lines).

SUBSCRIPTIONS, HOME AND FOREIGN.

"ENGINEERING" may be ordered from any newsagent in town and country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance :—

For the United Kingdom	£3	5	0
For Canada—			
Thin paper copies	£2	18	6
Thick paper copies	£3	3	0
For all other places abroad—			
Thin paper copies	£3	3	0
Thick paper copies	£3	7	6

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines, or under, and one shilling per line up to one inch. The line averages six words. When an advertisement measures an inch or more the charge is 12*s.* per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns, of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but cannot be guaranteed.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

CONTENTS.

	PAGE
Temperature of Flame Gases (*Illus.*)	241
Literature.—Factory Layout Planning and Progress. Early British Locomotives. Modern Steels. A Romance of Industrial Engineering	242
The Engineering Outlook.—VII	243
The Harland Trailer Fire Pump (*Illus.*)	245
Modern High-Pressure Water-Tube Boilers (*Illus.*)	246
Sedimentation and Flocculation	248
Centralised Control of Coal-Washing Plant (*Illus.*)	250
The Heat-Treatment of Steel by High-Frequency Currents	251
Annuals and Reference Books	252
Tenders	252
Books Received	252
Personal	252
Notes from the North	252
Notes from the South-West	253
Notes from Cleveland and the Northern Counties	253
Notes from South Yorkshire	253
Notices of Meetings	253
British Standard Specifications	254
The Coal-Mining Industry	255
Mechanical Engineering in Power Stations	256
Notes	257
The Institution of Mechanical Engineers	258
Letter to the Editor.—Load Tests of a 4,000-kW Combustion-Turbine Set	259
The Chamber of Shipping of the United Kingdom	259
28-H.P. Track-Laying Tractor (*Illus.*)	260
The Action of Water on Copper Pipes	260
Labour Notes	262
Forty Years' Development in Mechanical Engineering Plant for Power Stations (*Illus.*)	263
The Society of Glass Technology	264
"Pistonair" Reversible Single-Drum Hoist (*Illus.*)	265
Modern Tanker Design	266
Catalogues	267
"ENGINEERING" Patent Record (*Illus.*)	268

Two One-Page Plates.—MECHANICAL ENGINEERING IN POWER STATIONS.

ENGINEERING

FRIDAY, MARCH 8, 1940.

VOL. 149. No. 3869.

THE COAL-MINING INDUSTRY.

THE publication of the annual reports of the Secretary for Mines and the Chief Inspector of Mines provides an opportunity for taking stock of one of Britain's leading industries, the importance of which at the present time can scarcely be exaggerated. So many industries are dependent upon the coal industry that the latter may with justice claim to be not only a basic industry, but also to form an integral part of the economic resources of the country, and as such it represents an important factor in the struggle in which the nation is now engaged. Owing to the considerable amount of statistics involved it is obvious that a certain time lag must occur between the expiration of a given period and the publication of a comprehensive statistical report dealing with it. The reports, which were recently published, are for the year ended December 31, 1938, and are bound together in one volume.*

An outstanding event, which marks a turning point in the economic development of the British coal industry, was the passage of the Coal Act, which received the Royal Assent on July 29, 1938. The Act consists of three parts, which are interrelated and complementary. Part I provides for the unification of coal royalties under the ownership and control of a Coal Commission ; Part II provides for the furtherance of reorganisation in the industry by transferring to the new Coal Commission the functions of the Coal Mines Reorganisation Commission, and by varying the powers of compulsory amalgamation given to the latter body by the Coal Mines Act, 1930 ; and Part III extends to the end of 1942 the duration of Part I of the Act of 1930, which is the statutory basis of the organised selling schemes, and includes certain amendments designed to strengthen, in the interests of consumers, the Committees of Investigation constituted under that Act.

Passing from the question of legislation to that of output, the year under review may be said to be remarkable for the considerable fall in production which took place, in contrast with the increases in recent years. The world output in 1938 is estimated at about 100 million tons less than that of the preceding year, and amounted to approximately 1,190 million tons. Over 90 per cent. of this reduction took place in the United States, where the output declined by over 95 million tons, or 21·4 per cent., compared with 1937. The output in the European coalfields (excluding the U.S.S.R. and Spain) fell by only 10 million tons, being about 555 million tons. In Great Britain, production declined by 13·3 million tons, and in Holland by nearly a million tons. On the other hand, the Polish output (excluding Karwin) increased by 1·8 million tons, the French by over two millions, and the German (including the Saar, but excluding Austria and Sudetenland) by about 1·7 million tons. In Russia, output increased by over 10 million tons. The output in Czechoslovakia is estimated at about 15 million tons for the year 1938.

Great Britain's output of coal amounted to 227 million tons, which was 13·5 million tons less than in 1937, and nearly 1·5 million tons less than in 1936, but 4·75 million tons more than in 1935. There was a heavy fall in the quantity of coal shipped abroad, the total shipments (including foreign bunkers and the coal equivalent of the coke and manufactured fuel exported) amounting to 49·7 million tons, as compared with 56·3 million tons in 1937. Actually, the quantity shipped fell to below the 1936 figure of 50·3 million tons, and, apart from years affected by national stoppages, was lower than in any year since the Great War. The quantity of coal available for consumption for all purposes in Great Britain amounted to over 175 million tons, which was about 6·7 million tons less than in 1937 and 0·75 million tons less than in 1936. The recession in 1938 marked the end of a rise which had been continuous since 1929. The iron and steel industry was mainly responsible for the decline, the quantity of coal which it consumed having fallen by nearly 5 million tons, as a result of the reduced scale of working in this industry as compared with 1937. Coal consumed by general manufacturers was a million tons lower, and locomotive coal half a million tons lower. Gas and electricity works maintained their consumption at slightly above the record figure of 33 million tons for the preceding year.

With regard to actual mining operations, it is of interest to note that mechanical mining in this country is still increasing. The number of mechanical conveyors in use increased from 7,300 in 1937 to 7,826 in 1938, which is nearly three times as many as in 1928, and the total quantity of coal mechanically conveyed in 1938 was 123 million tons. The replacement of compressed-air machines by electrically-driven machines continued, and in 1938 the proportion of the total number of machines driven by electricity was 60 per cent., as compared with 58 per cent. in 1937. The proportion of coal-cutting machines driven by electricity continued to increase and amounted to 66 per cent. in 1938, as compared with 64 per cent. in the preceding year. The quantity of coal cut by machinery in 1938 was 135 million tons, a decrease of about 2 million tons compared with 1937. The proportion of the total output cut by machines, however, has risen from 57 per cent. in 1937 to 59 per cent. in 1938.

A rapid advance is being made in the use of pneumatic picks, both for ripping and similar work and for coal getting. Picks in use for coal getting increased from 7,621 in 1937 to 8,935 in 1938, and for ripping and similar work from 3,824 to 4,202. The quantity of coal dealt with by picks reached a figure of 15 million tons, including 3·7 million tons obtained in conjunction with coal-cutting machines, as compared with 13·75 million tons in 1937, and a little over a million tons in 1928. The percentage of mechanically-cleaned coal rose to 45·4 per cent. in 1938, as compared with 43·8 per cent. in 1937, although the tonnage of cleaned coal produced was

* *18th Annual Report of the Secretary for Mines for the Year ended December* 31, 1938, *and the* 31*st Annual Report of H.M. Chief Inspector of Mines for the same period, with a Statistical Appendix to both Reports.* London: H.M. Stationery Office. Price 4*s.* net.

actually some 2 millions less, with a total of 103·2 million tons in 1938. The number of cleaning plants in operation during the year increased by 27.

Turning now to oil products from coal, the returns show a production of 105 million gallons of refined motor spirit, mainly from coal, which compares with 100 million gallons in the preceding year and 54 million gallons in 1934. The output of petrol from the hydrogenation plant at Billingham increased by 21 per cent., that is, from 35 million gallons in 1937 to 42·3 million gallons in 1938. The Scottish shale-oil industry produced more of the heavier types of oil in 1938 (*i.e.*, Diesel, gas and fuel oils) at the expense of motor spirit and naphtha, the production of which decreased by 11 per cent. The consumption of pulverised fuel in 1938 was 6·1 million tons, an increase over 1937 of only 28,000 tons; compared with 1929, however, the increase in the use of pulverised coal is marked, being equivalent to 129 per cent.

The total output in 1938 of mining and quarrying industries other than coal amounted to nearly 116·25 million tons, with a net selling value at the mine or quarry of over 26 million pounds, the number of persons employed being 103,000. There was little change between these figures and the comparable returns for 1937. With the increasing use of machinery and explosives, the average daily output of mineral per wage-earner continued to increase; thus, from 2·67 tons in 1929 the figure rose to 4·20 tons in 1937 and 4·34 tons in 1938. Most of this increase is accounted for by the minerals more easily won, namely, gravel and sand, clay shale, etc., limestone and chalk, the aggregate output of which, in 1938, increased by 85 per cent. over that of 1929, while the average number of persons employed increased by only 7 per cent. The production of iron ore and ironstone used for iron making during 1938 showed a decrease of 17 per cent. compared with 1937, the output being 11·8 million tons as against 14·2 million tons. The latter figure, however, represented a peak.

The annual report of the Chief Inspector of Mines for 1938 deals mainly with accidents. At mines affected by the Coal Mines Act (1911), which includes mines of coal, stratified ironstone, shale and fireclay, the average number of persons employed in the year under review was 178,872 at the surface, and 623,571 underground. The number of persons killed by accidents at these mines was 858, and 3,157 were seriously injured. The number of persons who were injured and disabled for more than three days was 131,776. The accident rates per 100,000 man-shifts worked above and below ground for the whole country were 0·41 killed, and 1·93 seriously injured during 1938, compared with 0·40 and 1·96 in 1937, and 0·39 and 1·92, respectively, in 1936. Of the 3,659 persons killed and seriously injured underground during the year, 1,797, or 49 per cent., were the victims of falls of ground; 1,018, or 28 per cent., of haulage accidents; 208, or 6 per cent., were killed or injured by gases, coal dust and fires; 65, or 2 per cent., by machinery accidents; and 571, or 15 per cent., by various miscellaneous causes.

Fatal accidents resulting from falls of ground numbered 408, and 1,389 persons were seriously injured from the same cause during the year. Compared with 1937, there were decreases of 28 in the number killed and of 127 in the number seriously injured. In connection with the high proportion of accidents due to falls of ground, special attention is given in the report to the number of accidents which occurred in that part of the face in mechanised mining, which, lacking a better term, may be called the "cutter track," that is, the space between the coal face and the last set row of props. Descriptions of falls occurring in this space are usually attributed to "an induced break at, or just in advance of, the coal face," and another induced break or slip along the line of the last row of props is frequently reported. On occasion, temporary props set in this space have been reeled out, and sometimes bars have been broken or reeled out. The need for better support of the cutter track has been urged by nearly all the divisional inspectors. Investigation and experience have demonstrated that the occurrence of induced fractures in the conditions described above, and parallel to the line of face, reappearing at regular intervals, must be regarded as almost inevitable. These fractures may be scarcely observable in their early stages of development, while those beyond the face must obviously be hidden from view and inaccessible to ordinary examination, their existence only becoming known after the fall has taken place.

MECHANICAL ENGINEERING IN POWER STATIONS.

The cumulative effect of improvements in engineering technique could hardly be better illustrated than by the advances which have taken place during recent years in the design and construction of plant for generating electricity. These advances have been fostered by the increasing consumption of electricity for all purposes, for, as this increased consumption has called for the construction of more and more generating plant, its production has, in turn, stimulated designers to improve on their previous efforts. As a result of this interaction, while the lowest coal consumption in any British power station in 1926 was 1·76 lb. per kilowatt-hour generated, the figure had fallen to 0·862 lb. by 1938, a reduction of 51 per cent. Similarly, during the same period, the maximum thermal efficiency had risen from 17·95 per cent. to 28·98 per cent., an increase of 65·5 per cent. The various steps which have rendered these improvements possible and the considerations which have led designers to adopt them cover much that is important from the point of view both of engineering history and of practice in other branches.

The choice by Sir Leonard Pearce of "Forty Years' Development in Mechanical Engineering Plant for Power Stations," as the subject of the 26th Thomas Hawksley Lecture, which he recently delivered before the Institution of Mechanical Engineers, was almost inevitable, in view of Sir Leonard's long association with this branch of engineering. The fact that he was the designer of two stations, Barton and Battersea, which, in turn, represented the most advanced practice in this country, heading the lists for low coal consumption and high thermal efficiency, gives particular authority to his diagnosis of the influences which wrought such changes in a relatively short time, and to his estimates of future trends.

In his lecture, an abridged account of which is commenced on page 263 of this issue. Sir Leonard reviewed the changes which have taken place in the 40 years during which he has been connected with the electricity supply industry. In that period, the reciprocating engine has given place to the turbine, steam pressures have advanced from about 150 lb. to 1,350 lb. per sq. in., and steam temperatures have risen from saturation level to 950 deg. F. These changes in themselves offered many problems for the engineer and the metallurgist to solve, and they have been accompanied by others, both mechanical and electrical, equally profound and far-reaching in the generating plant and other equipment. Not only has the design of the plant had to be constantly modified to meet the alterations in steam conditions, but it has had to be adapted to the constant demand for larger and larger units, which the ever-growing development in consumption has rendered necessary. Thus, the place of the 350-kW sets of 40 years ago has been taken by a unit of one hundred times that output, which can almost be regarded as standard, while others with outputs of 50,000 kW are common, and those of double that figure are probably only temporarily exceptional.

Plotted on a time basis, the successive stages in the evolution of modern generating plant show a remarkable acceleration. At the beginning of the century the steam pressure most generally adopted was, as we have said, about 150 lb. per sq. in., which was soon increased to about 200 lb. per sq. in., at which figure it remained for several years. The temperature was gradually increased to 600 deg. F., and "bled" steam feed-water heating was introduced to yield feed temperatures of about 180 deg. F. The next step was an increase in the steam pressure to about 350 lb. per sq. in., accompanied by an increase in steam temperature to about 750 deg. F. and in feed-water temperature to 250 deg. F. A further stage, which commenced only about eight to ten years ago in this country, was an increase in the pressure to 650 lb. per sq. in., associated with a steam temperature of 800 deg. F. and a feed-water temperature of 350 deg. Even more recently the steam temperature has been increased to 875 deg. F., while a further and very interesting step forward has been made in the construction of two stations using steam at 1,400 lb. per sq. in., with a temperature of 950 deg. F. and feed at 400 deg. F. These figures all relate to the straight regenerative cycle, for which most plants in this country have been designed.

It is interesting to compare this course of development with what has happened during the same period in the United States. Only the results of fairly recent metallurgical researches have made it possible to utilise temperatures above 750 deg. F. In the United States, however, the necessity for improving steam conditions arose rather earlier than with us, and attempts were made, therefore, to achieve the desired end by increasing the steam pressure to about 1,200 lb. per sq. in. To counteract the correspondingly high percentage of moisture which, as a result of these high pressures, occurred in the turbine exhaust, a reheat cycle was adopted. It is instructive to notice, however, that this policy is now being modified, and that plants are being designed for temperatures of 950 deg. F. and pressures of 1,300 lb. per sq. in. without the complication of reheating. Even with temperatures as high as 930 deg. F., which is the limit until metallurgists make further improvements, reheating is necessary, however, when very high pressures are used. This practice is illustrated in the recent extensions at the Brimsdown station in this country and at the Twin Branch station of the American Gas and Light Company. How the improvements in terminal conditions have increased the possibilities of attaining high station efficiencies is shown by the statement that the overall operating efficiency has risen from less than 10 per cent. to about 30 per cent. during the period of 40 years.

Another difference between practice in this country and in the United States lies in the use of "superimposition," the turbine engineer's equivalent to the practice of "McNaughting" beam engines, introduced nearly a century ago. This consists in installing extra high-pressure turbines, the exhaust from which is utilised in the existing low-pressure machines. To provide steam for these "topping" units, new extra high-pressure boilers are required, but on the turbine side the new plant merely comprises small high-speed units which can often be accommodated in the existing turbine room without any heavy building costs. It would seem that the adoption of this practice in the United States was due, at least in part, to a slowing down in the rate of increase of the electrical demand, which has been evident during the past ten years. In a report on "Progress in Power Generation," which appeared in the January issue of *Electrical Engineering*, it was stated that, during 1939, ample generating capacity was available with a sufficient margin to meet a considerable increase in load, and it appears that, since 1933, practically no new large generating stations have been built and very few small ones. Such increase in capacity as has been necessary has been obtained by superimposition, though it is now beginning to be realised that this may be no more than a temporary expedient. So far, the continually-increasing demand for power, combined with the interconnection of our principal stations, has minimised the advantages of this policy in the eyes of British engineers. As we pointed out, however, in discussing the review by Messrs. H. C. Lamb and K. Baumann of American power-station practice, two years ago, it may become necessary to adopt this course before long, owing to the shortage of suitable sites for large power stations. Since then the Loeffler plant at Brimsdown has come into operation, and Sir Leonard is installing a primary set working at 1,350 lb. per sq. in. and exhausting into a secondary set at 600 lb. per sq. in. at Battersea. These "superimpositions," however, are virtually new plants, and cannot be rigorously compared with what has taken place in the United States, where

high-pressure boilers and turbines have been superimposed on already existing equipment.

Another point in American practice, which received a good deal of attention in the discussion on the paper by Lamb and Baumann, was the policy of installing one boiler per turbine. Even in the United States, however, this practice has not gone very far, and even where it has been adopted the choice may have been determined by the necessity of using pulverised fuel. In dealing with this question, Sir Leonard points out that such a scheme envisages an availability factor for the boiler comparable with that of the turbine, and that statistics and operating experience do not, in general, appear to justify such an assumption as yet. Whether opinion on this subject will change as the reliability of boilers increases remains to be seen. For the moment, a reasonable compromise between capital expenditure and continuity of supply seems to be to provide two boilers per prime mover, the rating being such that, at their individual economic outputs, each can supply 50 per cent. of the total steam demand, while at their maximum continuous ratings they can deal with about 65 per cent. of the load. It can hardly be denied that, at the moment, the boiler and its auxiliaries is the most interesting part of the station. Sir Leonard gave a great deal of useful information about this branch of engineering.

There is space to deal with only one more of the many points which he raised. Some years ago, when the efficiency of steam stations was of the order of 20 per cent. to 22 per cent., with heat-consumption rates of 17,000 B.Th.U. to 15,500 B.Th.U. per kilowatt-hour, attempts were made to utilise other systems and much attention was paid to the binary fluid mercury cycle, especially in the United States. Plants utilising this cycle were, in fact, installed in more than one area. It is known, however, that these have not been altogether satisfactory in practice. Considerable trouble has been experienced with the boilers installed at Kearney and Schenectady, and the former has been completely replaced. The new boiler has only one drum, and "porcupine" tubes with internal cores and close clearances have been eliminated. The convection surface, instead of being completely filled with a liquid, carries a mixture of liquid and vapour, so that the amount of mercury required per unit of heating surface is much reduced, although, by reason of the elimination of tube cores, the total quantity of mercury in the boiler is somewhat increased. In spite of various improvements, the boiler retains a number of complications, and, as Sir Leonard points out, its adoption is being retarded by the steady improvements which have taken place in the steam cycle. Heat rates of 11,000 B.Th.U. per kilowatt-hour have, in fact, been obtained on certain steam plants, and even lower figures are contemplated for new stations at present under consideration.

A study of the lecture leads to the conclusion that British engineers may well be proud of the improvements that they have brought about in power-station design, especially during recent years. The units generated annually by British stations have increased by 437 per cent. in the 17 years from 1920 to 1937, an expansion which represents a continuous and powerful inducement to designers to enlist to the fullest extent the co-operation of chemists and metallurgists, as well as of civil, mechanical and electrical engineers, in realising the benefits of the latest researches in their several sciences and crafts. So long as they continue, as Sir Leonard points out, to appreciate the importance of avoiding set ideas and of maintaining a broad view, progress in the future should be well maintained.

UNITED STATES IMPORTS OF MANGANESE ORE.—Statistics compiled by the Bureau of Mines at Washington show that, during 1939, the United States imported 698,490 long tons of manganese ore, containing 35 per cent. or upwards, of the metal, and representing 341,816 tons of manganese. Soviet Russia supplied 29 per cent. of the total, the Gold Coast 22 per cent., India 16 per cent. Brazil 15 per cent., and Cuba 15 per cent. In addition, 30,684 tons of ore containing 29 per cent., or 8,898 tons of manganese metal, were imported from the Union of South Africa.

NOTES.

THE MACHINE TOOL TRADES ASSOCIATION.

OVER 100 firms were represented, on February 29, at the luncheon which the Machine Tool Trades Association substituted, this year, for the customary annual dinner. The large gathering included many notable guests, including a number from France, in compliment to whom the toast of "The President of the French Republic" was honoured with that of "H.M. the King." The President of the Association, Mr. Harold J. Butler, M.B.E., who occupied the Chair, then proposed the toast of "His Majesty's Government and the Success of the Allies." There were many difficulties in the production of machine tools, he said, but the Government could rely upon the determination of the industry not to falter in its task. The Minister of Supply, the Right Hon. Leslie Burgin, P.C., LL.D., M.P., responded. He knew, he said, that the great machine-tool industry had realised that the war was one of machines and material, as well as men. He believed that some 35,000 persons were engaged in the industry, and would like to see that number trebled. He quoted a letter from his French colleague, M. Dautry, Minister of Armaments, in which the hope was expressed that labour would be economised. It was, indeed, necessary to economise for military purpose. The Ministry appreciated the efforts that were being made, and approved the way the industry had set its house in order in the way of training semi-skilled men, improving design, and so forth. The cost of machine tools in this country compared very favourably with similar classes of imported machines. But the war would not win itself, and its prosecution called for all the talent and all the energy in a minimum of time that masters and men were capable of. Sir Alfred Herbert, K.B.E., in proposing the toast of "The Chairman," said that he was sure members would be glad to hear that the Council had that morning invited Mr. Butler to continue in office for a further period. He supported whole-heartedly Mr. Burgin's eloquent appeal for sustained effort, and thought more machine shops should run night as well as day than was the case at present.

THE WORK OF THE IMPERIAL INSTITUTE.

The circumstances of the time have naturally affected the operations of the Imperial Institute. In particular, its educational work has been interfered with by the closing of the exhibition galleries. The loan of Empire films to schools, however, which during the evacuation period showed great falling-off, has now recovered, and is as active as ever, a source of demand, in addition to the schools, having arisen from military camps and training centres. In the main work of the Institute—the furnishing of information and the carrying out of investigations on the use of Empire products—the incidence of the war has served only to accentuate the value of its activities. Sir Harry Lindsay, the Director, states, in the Annual Report for 1939, which has just been published, that about half the technical and scientific staff is working with one or other of the emergency ministries, but that as the number of enquiries received from Empire Governments, producers or merchants has also been reduced to about half, it is still possible to cope with the work in a satisfactory way. The fact that requests for information on the use of mineral, animal and vegetable products of Empire origin should show some falling-off, in the disorganisation of the first few months of a war, is not surprising. The report with which we are dealing covers only the first four months of the war period, and it would appear probable that the new conditions will ultimately result in an actual increase in the activities of the Institute. A more general realisation of the importance of fostering Empire trade should, in itself, result in increased demands on this centre of information and investigation, but, in addition to the general incentive, very many cases are likely to arise in which the desirability, or even the necessity, of substituting British products for those of enemy origin will result in demands for information and reports. Already examples of this effect are to be seen, as for instance, in an inquiry from a cement firm for British sources of trass, with properties similar to German trass, which is a decomposed volcanic rock resembling pumice. The Institute was able to advise the inquirer that deposits of similar material existed in Cyprus and New Zealand. The firm was subsequently supplied with samples of volcanic material from Malaya, which tests carried out at the Institute some years ago had shown to possess considerable pozzolanic properties. This instance must serve as a single example of the type of service performed by the Institute. Details of a large number of others will be found in the reports, but actually the information given there is not exhaustive as, in the Mineral Resources Department alone, 110 investigations, involving the examination of 322 samples and 1,097 requests for information, were dealt with during the year.

THE INSTITUTION OF STRUCTURAL ENGINEERS.

With a commendable optimism, which was entirely justified by the results, the Institution of Structural Engineers held its annual dinner at the Dorchester Hotel, Park-lane, London, W.1, on Friday, March 1. In proposing the toast of the Institution, Colonel J. G. Llewellin, Parliamentary Secretary to the Ministry of Supply, referred to the supply of materials for structural work and mentioned that an economy committee had been set up to look into the requirements of the Service departments with respect to timber and to ensure that no waste occurred. Steel, he said, was being made at a rate never before equalled in the history of the country, and other home-produced materials were in ample supply; it was necessary, however, to see that all were used to the best advantage. Referring to the new Government factories being erected in the North, he said the design, construction and supervision had been divided between independent firms, and on one site 36 engineers and 20 architects were working happily together; thus adversity made strange bedfellows! In conclusion, he expressed the hope that structural engineers and others would soon be able to apply their minds to constructive efforts for building up the happiness of mankind. The response to this toast was made by Mr. Percy J. Black, President of the Institution, who occupied the chair. In the course of his remarks, Mr. Black alluded to the happy association of architects and engineers mentioned by Colonel Llewellin, but pointed out that if the present team spirit were scrapped it would be difficult to restore it at a later date when the work of reconstruction had to be undertaken. He concluded by offering, on behalf of the Institution, every possible help to the Ministry of Supply in their work. The toast of the guests was proposed by Mr. M. B. Buxton and the response was made by Sir Clement D. M. Hindley. The dinner, which was followed by a dance, was attended by some 400 members and guests, and in the existing circumstances the Institution, particularly those responsible for the organisation, must be congratulated on the success achieved.

WOMEN'S CONTRIBUTION TO WAR-TIME ENGINEERING.

When the contribution which can be made by women to munition production is considered, it is natural to think in terms of the work which they performed in the last war. As is well known, very large numbers of women were then employed for a variety of semi-skilled operations, and it is not too much to say that their work in this direction played a vital part in the ultimate success of the Allies. The question of their employment in a similar capacity on a large scale in the present war is now under discussion, and while no decision has yet been reached as to the extent to which dilution by female labour is desirable, there is some indication that, ultimately, it may be found advisable to equal or even exceed the figure attained in the last war. There is, however, another aspect of the employment of women in engineering work which, hitherto, has hardly been considered. Primarily as a result of the work done by them in the last war, a limited number of women adopted engineering as a professional career, and it is of interest to consider the possibility of the employment of women at the present time in executive positions. Immediately after the last war, the Hon. Lady Parsons, wife of

Sir Charles Parsons, founded the Women's Engineering Society, with the object of forwarding the interests of those women whose association with engineering did not cease with the declaration of peace, and of keeping before the public the possibilities of engineering as a profession for women. While it is unlikely to be disputed that many of the executive positions in the engineering industry can only be filled by men, there are also a number of positions, which, in the absence of prejudice, could equally well be filled by women, and it may be, therefore, a matter for regret that the severe trade slump of the early 'twenties had a disastrous effect on women's ambitions in this direction. The Women's Engineering Society, however, continued to exist, and performed what may prove to be a valuable service in furthering the interest of professional women engineers. The present position of the professional woman engineer is indicated by the fact that at a luncheon held on Monday last, March 4, to celebrate the coming of age of the Society, Miss Caroline Haslett, the President, read a message of congratulation from Her Majesty the Queen, while the principal speaker was the Rt. Hon. Ernest Brown, Minister of Labour and National Service. While it is premature to speculate on the contribution which may ultimately be made by professional women engineers to our war effort, a useful step has been taken by the inauguration of classes for training women of good educational qualifications to occupy positions of responsibility as forewomen and supervisors in works where large numbers of women operatives are employed.

The Port of Townsville.

The port of Townsville, Queensland, not only serves a very extensive grazing, mining and sugar-growing area in that State, but is a natural channel of communication with New Guinea and the Melanesian islands generally. In addition to its important exports of sugar, zinc concentrates and silver lead, the port has recently acquired a new significance as one of the scheduled bases on the air-mail route between the United Kingdom and Australia. More than local interest attaches, therefore, to the recently-issued report of the Townsville Harbour Board for the three years 1936 to 1938, inclusive. The stable character of its normal trade is well illustrated by the very small fluctuations in the number of vessels using the port, the actual totals being 649, 646 and 647, respectively, in the three years under review. The corresponding tonnages, however, indicate some increase in the average size of vessel, being, respectively, 2,263,759, 2,482,250 and 2,445,294, and thus justify the policy of the Board in continuing to improve the approaches. From January to July, 1936, the Board's dredger was employed in opening out the channel leading from the entrance to Ross Creek, to enable coastwise steamers to land timber directly at the Inner Harbour wharves. For the next 18 months, work proceeded continuously in the Platypus Channel (the sea entrance), and the basin and berths in the Outer Harbour; and in February, 1938, the dredger commenced to widen the approach channel by 120 ft. on the western side. Work on the flying-boat base began in May, 1938, and was completed on September 15 in that year. The site is within the protection of the breakwaters, and the excavated area has a length of 670 ft. and a minimum width of 300 ft. Some 90,000 cub. yds. of material were removed at an average cost of 1*s.* 10·68*d.* per cubic yard, increasing the depth from 2 ft. to 14 ft. at low water, ordinary spring tides. Following an experimental flight by the flying-boat Centaurus, regular calls were inaugurated by the arrival of the Challenger on July 5, 1938; and between that date and the end of the year, 146 calls were made by east-bound or west-bound flying-boats. Reference has been made to sugar, zinc concentrates and silver lead as being the principal items in the trade of Townsville. In the three years considered, the exports of raw sugar amounted to 114,523 tons, 127,441 tons and 118,594 tons, respectively; those of zinc concentrates, to 44,039 tons, 61,241 tons and 58,574 tons; and of silver lead to 33,713 tons, 42,144 tons and 37,700 tons. Frozen meat is also an item of consequence, the corresponding shipments being 19,804 tons, 23,213 tons and 22,417 tons. The principal single item of inward commerce, apart from "general" cargoes, was oil, amounting to 39,899 tons, 48,109 tons and 45,646 tons, respectively. Increases are evidently expected in all these items, and the consulting engineers to the Board, in drawing up a list of recommended additional works for the development of the harbour, have proposed the construction of a new berth for the handling of oils and explosives, and a new reinforced-concrete pier, with mechanical handling plant and improved storage arrangements for dealing with the trade in concentrates, sugar and lead.

Shipbuilding in the United States.

Statistics compiled at the close of 1939 by the National Council of American Shipbuilders and published recently by the President of the Council, Mr. H. Gerrish Smith, show that 40 steel sea-going merchant ships, totalling 335,200 gross tons, were launched in the United States during 1939, and that 28 vessels, which were launched either in 1938 or 1939, were delivered to their owners during 1939. In these totals only vessels of 1,000 gross tons and upwards are taken into account, and smaller vessels and tugs, ferry boats and barges, built on the sea coast, in river ports, or on the Great Lakes, are not included. Commenting on these figures, the New York *Marine Journal* states that of the 28 ships delivered during the year, none of which was of less than 7,400 tons, 11 were oil tank vessels, 14 were high-speed cargo ships, and three were passenger and cargo steamers. These last three ships were the S.S. Panama, Cristobal and Ancon, built by the Shipbuilding Division of the Bethlehem Steel Company for the Panama Railroad. In addition to their work on merchant ships, commercial shipyards in the United States had under construction 38 naval vessels, aggregating 209,620 displacement tons, at the beginning of 1939. Of these, 16 ships, having a total displacement tonnage of 32,740, were delivered to the U.S. Naval Department during the course of last year. Meanwhile, contracts for 14 additional ships, of an aggregate displacement tonnage of 64,845, were placed by the Navy Department with private shipbuilding firms during 1939. Furthermore, orders for merchant ships of 1,000 tons gross and upwards received during 1939 by American shipyards, from the United States Maritime Commission or from private shipowning firms, represented 108 vessels, making together 833,355 gross tons. The smallest of these ships will be a vessel of 5,200 tons, and the others will range from 6,400 tons to 11,400 tons.

THE INSTITUTION OF MECHANICAL ENGINEERS.

An extra general meeting, in connection with the Steam Group, was held by the Institution of Mechanical Engineers at Storey's-gate, St. James's Park, London, S.W.1, on Friday, March 1. The chair was occupied by the President, Mr. Asa Binns.

Water-Tube Boiler Circulation and Design.

The business before the meeting was the reading and discussion of a paper entitled "The Circulation of Water and Steam in Water-tube Boilers, and the Rational Simplification of Boiler Design," and was presented by Mr. W. Yorath Lewis and Mr. Struan A. Robertson, B.Sc.(Eng.). An abridgement of it will be given in a subsequent issue.

After some introductory remarks by the President, in which he said that the part of the paper dealing with boiler design was controversial, but in spite of the differences of opinion still current, engineers must admit that great progress had been made in the technique of steam raising, the discussion was opened by Mr. A. F. Webber. It would appear, he said, that in concentrating on questions of circulation, other serious problems might be lost sight of. Referring particularly to a design for a Lewis single-drum stoker-fired boiler given in the paper, the side-walls of the combustion chamber were only very partially water-walled by tubes radiating from the drum; further protection was needed. He also thought that the amount of convective heating surface was inadequate.

Mr. J. Hamilton Gibson considered the elimination of the water drums in the Lewis boiler to be a desirable feature in the design, since in three-drum types of boiler the water-drums were frequently a source of trouble. Moreover, in this latter type of boiler, the failure of a tube in the middle of a nest often involved the cutting-out of numerous other tubes to get at the defective one. In the Lewis design, any one tube could be removed without disturbing its neighbours. There were, further, no untried features which might give rise to doubt. Referring to the particular design mentioned by the last speaker, he thought the bank of Field tubes at the gas outlet of the boiler formed a useful economiser. In his opinion, the Lewis boiler was a step in design worth further consideration.

Dr. William Abbott, who had been concerned with the installation of the first Lewis boiler,* installed in the Northampton Polytechnic Institute, said he had learned that it had given no trouble whatever. He felt that, from its inherent lightness and simplicity, the boiler had a good chance of establishing itself for use afloat. The more theoretical and experimental side of the paper was of great interest, and the authors had discarded conventional methods of investigation with success. The calculations as to velocities and so forth given in the paper were certainly more convincing than those formerly used. The authors, moreover, had not accepted Yarrow's well-known demonstration, which purported to show that the heating of the downcomer tubes was immaterial. Yarrow's conclusions were arrived at from experiments with small-scale apparatus. The authors had used full-size apparatus and had shown conclusively that the flow in one direction in a heated downcomer tube was unstable. The downcomer in the Lewis boiler could not be heated. Evidently there was room for more investigation in stability of flow and he hoped that the Institution would encourage Mr. Robertson to proceed further with his investigation.

Mr. Charles Erith, while agreeing that the Yarrow boiler, which had no unheated downcomers, seemed to upset all circulation theories, said that this type was a favourite one for certain warships which involved very severe fluctuations in steaming duty. Mr. Erith then commented on some early tests of the Niclausse boiler which, like the Lewis boiler, employed the Perkins-Field-tube principle. The efficiencies claimed in these tests were too high and that obtained from the first Lewis boiler, viz., 66 per cent., was more like what he would expect. He thought the claims made in the paper for the Lewis boiler could hardly be extended to modern base power house boilers as they were based on the performance of two relatively small examples only.

Mr. R. F. Davis commenced his remarks by saying that the first part of the paper, dealing with the changes of water to steam, was of special interest to him. In his own paper, accepted by the Council for future presentation, the same ground had been covered to some extent, but the analysis was developed much further. He might say, however, that experiments with pure, or nearly pure, water at atmospheric pressure might not represent what happened with chemically-treated boiler water at high operating pressures. The analysis of the circulation in a U-tube was very good, but he would take exception to the statement that it was not practicable to analyse the circulation in modern types of boiler. A method, which he considered gave a good working approximation, had been described in a paper read before the Institution in Manchester in 1933, by Mr. Timmins and himself. He saw no necessity for the setting up of a simple type of boiler as a standard of excellence, which standard might suffice for calculation but might not be a standard for performance.

Mr. G. A. Plummer fully appreciated the difficulties of attempting any complete analysis of the circulation in normal types of natural-circulation boilers, and the many tube failures reported in such boilers would appear to support the view that circulation in such boilers was frequently defective. The forced-circulation boiler, with correctly-proportioned water flow controlled by nozzles at

* See Engineering, vol. 139, page 453 (1935).

the entrance to each tube, had positive circulation and although power was required to force the water through the nozzles, yet the heating surface could be disposed in the most efficient way. Thus, in a case within his knowledge, the saving in mechanical draught power had more than counterbalanced the expenditure in pumping power, apart from advantages accruing from considerations of weight, space, and so forth. He would like some information as to the effect on the water level of the Lewis boiler from a sudden change of load. Some further information as to the physical formation of steam would also be of interest as experiments carried out, with unheated downcomers, by himself and others, led to somewhat different conclusions to those given in the paper.

Captain R. E. Trevithick was of opinion that the forced-circulation boiler had received less than justice in the paper and cited data as to the numbers and sizes of these boilers now in service. There were individual boilers with output capacities of the order of 300,000 lb. per hour and working pressures of 1,500 lb. per square inch, the combustion chamber heat releases approaching 700,000 B.Th.U. per cubic foot per hour. Since the Lewis boilers described in the paper were very much smaller than this, he thought the authors had not sufficient evidence on which to criticise the forced-circulation boiler.

Mr. W. A. Stanier, vice-president, on being invited from the chair to contribute to the discussion, pleaded little knowledge of the water-tube boiler. The only one that had been tried on a British locomotive was due to the initiative of Sir Nigel Gresley. The boiler had been constructed by one of the most prominent makers of water-tube boilers in the country yet he believed that a major trouble was the doubt as to which way the boiler would circulate. One of the great difficulties for locomotive water-tube boiler design in this country was the difficulty of getting one to lie within the English loading gauge and yet provide the necessary fire-box space for proper combustion of the amount of fuel required.

Major William Gregson, in concluding the discussion, said that he thought the authors had very definitely made out a case for the unheated downcomer. No boiler, he considered, except one with very low rating, was, from a circulation point of view, really safe unless it had a downcomer system of some sort which was not subjected to heat. He agreed with the authors as to the necessity for high rates of gas feed, but he thought that they had not fully realised that the designer of a modern boiler was not tied by providing only for absorption of heat. The problem in modern boilers was to burn the very large amount of fuel that was necessary, in unit time. Older design called for a large amount of brickwork in the furnace but with modern rates of combustion this brickwork would fuse, hence the now common adoption of water walls. The design of the Lewis boiler did not lend itself to adequate water walls.

Major Gregson then criticised some details of the large boiler illustrated in the paper and referred to earlier in the discussion. He was not very certain what would happen in the Lewis boiler with a definitely salt feed, such as might be met with at sea. It had been claimed in the paper that there was a radical saving of weight from the elimination of water drums, but this might be largely negatived by the use of Perkins-Field tubes which were, of course, double.

The President, in proposing a vote of thanks to the authors, suggested that, as the hour was late, the various points raised in the discussion could be answered more fully in writing. Mr. Lewis, therefore, made only a rapid survey and reserved details for discussion in the *Proceedings*. Mr. Robertson also spoke briefly, and the meeting then terminated.

COMMERCE BETWEEN BRITISH GUIANA AND CANADA.—During the year ending March 31, 1939, Canadian imports from British Guiana—which consisted mainly of raw sugar and bauxite—were valued at 7,027,873 dols. In the same year the Dominion exported, to British Guiana, paper and rubber manufactured goods, lumber, base metals, electrical apparatus and foodstuffs, of an aggregate value of 1,370,925 dols.

LETTER TO THE EDITOR.

LOAD TESTS OF A 4,000-KW COMBUSTION-TURBINE SET.

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent, "M.I.Mech.E." (page 122, *ante*), has calculated compressor efficiencies from the compression ratios and temperatures given in Table IV of my article in your issue of January 5, and arrives at different results from those given in the same table. A check has shown that an error was made by the translator in converting temperature differences from deg. C. to deg. F., and that the figures given for adiabatic temperature rise and measured temperature rise, under the sub-heading "Compressor Power," should be 32 deg. F. lower in each case. Since, however, the efficiencies were calculated from the original Centigrade readings, they are not affected by this error.

The compressor efficiencies published in my article will be readily confirmed within a fraction of one per cent. if calculated either from the temperatures and pressures given in the first four lines of Table IV, from the corrected values referred to above, or from the original Centigrade readings which were published in the *Schweizerische Bauzeitung* of January 12, 1940, or *Le Génie Civil* of January 6, 1940.

Yours faithfully,
PROFESSOR DR. A. STODOLA.

Zürich. February 17, 1940.

THE CHAMBER OF SHIPPING OF THE UNITED KINGDOM.*

THE keynote of my predecessor's address at the last annual meeting was "Peace and Reconstruction." Mine must be "Victory and a Lasting Peace." There is no better indication of our determination and our capacity to win than the splendid record of the first six months of the war at sea. The shipping industry, in common with the whole nation, is filled with the profoundest admiration and gratitude to the Navy for their work in keeping the sea clear and enabling us to bring the food upon which we live and the supplies by which alone we can fight and win. Our industry is proud to have co-operated with the Admiralty in the preparations for that work, in its continuous improvement and its rapid adaptation to each new peril by the enemy. In particular, the Admiralty lent a ready ear to the industry's appeal to institute the convoy system from the first day of war. At the outset there were inevitable delays to shipping, but these have been greatly reduced by the continued co-operation of the industry with the Admiralty. While it is impossible under war conditions to maintain that regularity and dispatch which is our wont in peace, it is possible to effect greater and still greater economy of time, so that not an hour nor a ton is wasted.

The Government's decision to requisition all deep-sea liners as from February 1 and to extend generally the requisitioning of deep-sea tramps, which had to some extent been resorted to before that date, has been accepted loyally by the industry. I should not be honest if I pretended that the industry either welcomed it or believed it to be the best policy in the national interest. In announcing the Government's decision, the Minister of Shipping claimed that requisition would result in greater efficiency and economy. No one has a higher regard for the Civil Service than I, and particularly for the ability of those civil servants in responsible positions in the Ministry of Shipping, with many of whom we have worked in close harmony at the Board of Trade in the past; but experience shows that Government departments, by their very nature, their traditions and their methods of procedure, are incapable of running any business as efficiently or economically as the men trained in the hard school of business itself. This is particularly true of such an intricate and highly specialised business as shipping, where years of practical experience and the power of prompt decision are essential. Wisely, the Government has grasped that fact and has asked shipowners to run their own ships under the direction of the Ministry, and for the benefit of the nation. The success of requisition, therefore, will in a great measure depend upon the Government relying upon the incentive of the shipowners and their experience.

Wisely, also, the Government, from the outset, sought the advice and co-operation of many of our leading shipowners, who are to-day in charge of departments of the Ministry. Without wishing to be invidious, I would in particular mention Sir Vernon Thomson, the Principal Shipping Adviser and Controller of Commercial Shipping at the Ministry, to whom our industry owes more than they are ever likely to know. He and his colleagues are performing a vital service.

The Chamber has been engaged in prolonged negotiations with the Government in regard to rates of hire and conditions of charter for requisitioned vessels, and the outcome is naturally awaited with interest and anxiety. Although these negotiations are difficult, it is a pleasure to say that they are being conducted in a friendly atmosphere. Satisfactory charter conditions have been agreed, and I now hope that, after months of arduous work, the industry will succeed in securing rates of hire which will provide for operating costs and depreciation, and will, at least, leave a margin to cover a fair return on capital, sufficient to allow something tangible towards the building up of reserves which will be so urgently required at the end of the war. It would, I believe, be good policy for the Government to assure the industry that, as soon as the war is over, it will be ready to put into effect without further inquiry the assistance which was promised them in the British Shipping Assistance Bill, and that any additional assistance will be forthcoming which may then be shown to be necessary.

Recently the Government has proposed a scheme to provide insurance for vessels lost by war casualty, which is under active consideration. The problem of replacement of our tonnage is not, however, confined to war losses. Indeed, such losses may prove to be the smallest part of it. The real essence of the problem is to find means of building new ships for old as the latter wear out, of replacing ships lost by marine accidents, and obtaining fresh capital to increase our mercantile marine. If British shipping is to continue after the war, the industry must be put in a position to replace and add to its fleets, at whatever prices it may have to pay (and they are likely to be much higher prices), in order to maintain its services and to meet foreign competition.

Owing to Government indifference in the past, the position is far more serious in this war than in the last. The country entered the war with the financial resources of its shipping so reduced that the Government was prepared to support it by subsidies, grants and loans. Practically the whole of that assistance has now been withdrawn, or at least is in abeyance. Since the termination of the Great War, British shipowners have had to play a lone hand, for, with the exception of 4,000,000*l.* received over two years in subsidy in 1935 and 1936, they have received no help to fight their competitors; whereas, for one example, the beet-sugar industry has received from the British Government over 45,000,000*l.*, at the same time depriving our shipping of carrying between five and six million tons of sugar into this country and the Exchequer of about 15,000,000*l.* of duty which would have been payable on it.

The necessity for securing neutral tonnage has compelled the Government to pay neutral shipowners such rates of freights as make the hire which British shipowners are receiving look microscopical. Such enormous payments are rapidly enabling foreign shipowners to build up large reserves with which to intensify their already serious competition with British shipping. The withdrawal of British ships from their normal trading routes for war service opens the door still further to foreign competition. British shipping can only recover such trades, and, indeed, will only be able to hold its own in overseas trade generally if, after the war, it has the means to build and maintain superior, faster and more economical ships than other nations.

It is no good to rely alone upon financial aid from the Government after the war; the prudent and wise policy is unquestionably to enable the industry itself to begin now to accumulate reserves, which will at least help to meet the greatly increased cost of replacement.

There may be a few misguided persons who will urge that State control should be continued after the war, or even that the shipping industry should be nationalised. Let me remind anyone who thinks that nationalisation is a cure for the ills of British shipping of the experience of other countries in that field. After the last war the Australian Government tried running ships. They lost 12,000,000*l.*, and gave it up. The Canadian Government also remained in shipping: they lost about 6,000,000*l.* and then they gave it up. The losses which the United States Government has incurred in shipping ventures since 1918 are quite incalculable, but certainly exceed 600,000,000*l.* Shipping is an international industry, operating in peace time on an open world market; it is the most variable and fluctuating of all industries, and is also one of the most technical and highly specialised of business operations. This makes it the worst possible field for experiment by the State. I believe that the great majority of people in this country realise this, and that the nation will have the common sense after the war to let the shipowner get on with the job he understands better than any Government department.

* Presidential address by Sir Philip Haldin, delivered in London, at the 63rd Annual Meeting, on Thursday, February 29, 1940. Abridged.

28-H.P. TRACK-LAYING TRACTOR.

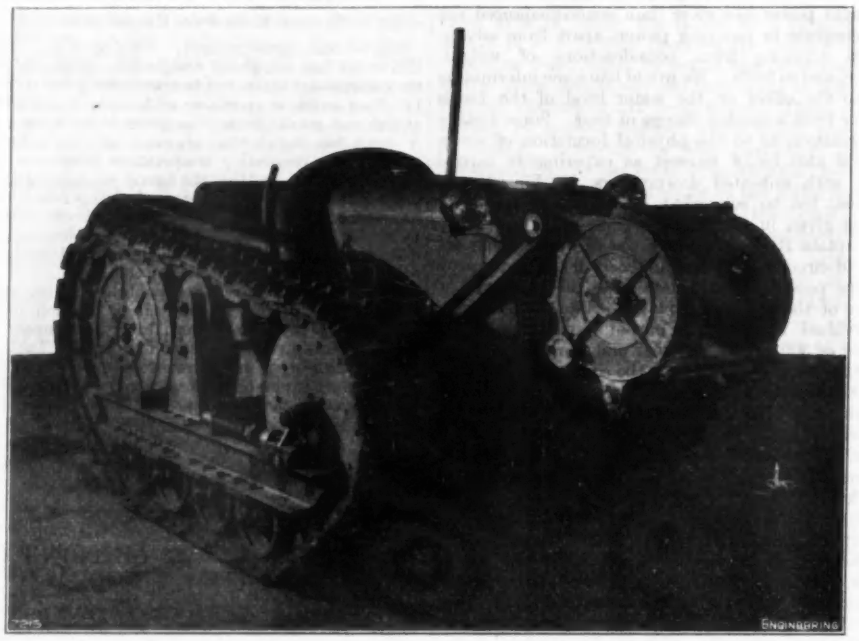
When describing the exhibits at the last Royal Show, held at Windsor last year, we dealt with a new tractor introduced by Messrs. David Brown Tractors, Limited, Meltham, Huddersfield. This was a petrol-paraffin model of the normal wheeled type, but since that date the firm has introduced the additional track-laying model illustrated in the accompanying figure. The new model embodies a number of the components employed in the wheeled tractor, in the form of a standard unit comprising the engine, gearbox, differential, together with the radiator, tanks and other parts. The front of this unit is mounted at a single point on a cross-member of a sub-frame, this frame also carrying the special final spur reduction gearing employed on the track-laying model. The sub-frame is constructed from standard structural-steel sections.

The drive from the engine is through a single dry-plate clutch, with a 10-in. diameter plate and ball-bearing throw-out, to a four-speed and reverse gearbox, the latter being combined with the differential. The drive from the differential is by the spur reduction gears referred to for the track hubs, upon which are mounted brake drums of large diameter, which serve both for braking and steering. Sprocket plates or rings are fitted to the periphery of the drums, and the drive is transmitted to the track shoes, on the inverted-tooth chain-drive principle, by means of a number of rollers mounted between the sprocket plates. The tracks provide a runway for four bogie rollers on each side, as shown in the illustration, while the slack side is supported in the middle by means of a fifth roller. The idler sprockets carrying the tracks at the front are provided with adjusting gear for varying the track tension, the adjusting screws abutting against recoil springs which serve as shock absorbers when exceptionally irregular obstacles are encountered. As suggested earlier, steering is effected by braking one or other of the hubs, independent hand levers, conveniently located for the driver, being provided for this purpose. The engine is the standard petrol type fitted to the wheeled tractors, and has overhead valves. With a compression ratio of 5½ to 1, this engine develops 28 brake horse-power at a governed speed of 1,400 r.p.m. The road speeds, at governed engine speed, on the four forward ratios, are 1·2 m.p.h., 1·75 m.p.h., 2·58 m.p.h., and 5·1 m.p.h., respectively; the road speed in reverse, also at governed engine speed, is 0·8 m.p.h. All the speeds can be stepped up *pro rata* by opening up the throttle to a second governor position, giving an engine speed of 2,500 r.p.m. A maximum governed road speed on fourth gear of 9·1 m.p.h. is thus attainable.

As will be clear from the illustration, the model shown is fitted with a winch which, apart from military service, may be usefully employed for working among timber or for the extraction of bogged vehicles. The winch drive is taken from the power take-off shaft of the tractor, located on the gearbox, by chain, and thence through the medium of a pair of bevel gears to a jackshaft. The latter carries a spur pinion engaging with a spur wheel mounted on the drum spindle. The ratio is such as to give a cable speed of 20 ft. per minute, which is sufficiently slow to avoid cable snatch. When operating at this speed, a cable pull of 15,000 lb. is attainable.

28-H.P. TRACK-LAYING TRACTOR.

MESSRS. DAVID BROWN TRACTORS, LIMITED, MELTHAM.



ACTION OF WATER ON COPPER PIPES.*

By Professor Dr. L. Tronstad and R. Veimo.

Although iron and steel mains are normally employed for the distribution of drinking water, lead or copper, being more corrosion-resistant, are usually preferred for the smaller-sized pipes used in domestic service, in order to avoid stoppage caused by the accumulation of corrosion products. A drawback to the use of lead pipes, however, is the risk of lead poisoning, which may occur with certain soft acid waters. Copper, on the other hand, is less poisonous than lead, amounts as great as 2 mg. per litre being stated to be non-toxic. For these and other reasons, copper has found extended application in domestic service systems in recent years. Nevertheless, the amount of copper picked up by the water is important, since, in the first place, water containing copper is liable to cause localised corrosion of iron pipes and aluminium utensils; secondly, copper acts as an oxidation catalyst in accelerating the destruction by detergents of the peroxide type of textile fibres, such as cotton and artificial silk; and thirdly, copper results in the destruction of vitamin C during cooking.

A number of investigations on the action of drinking water on copper pipes have been carried out in the past. Nachtigall* states that water which had stood for 9 hours in pipes one year after installation contained up to 5 mg. of copper per litre. Reichardt† found 7·24 mg. of copper per litre in ordinary drinking water from new mains, but only 0·8 mg. per litre in water from the same mains 13 years later. These and similar experiences seem to indicate that the copper content of the water decreases with the age of the copper mains, presumably owing to the formation of a difficultly-soluble protective film. According to Haase,‡ this film consists mainly of cuprous oxide, often containing a proportion of basic copper carbonates, together with calcium and magnesium compounds. Haase also maintains that, provided a reasonably protective film is formed, the attack on the metal will be negligible and the copper content of the water will not exceed 0·3 mg. per litre. The amount of dissolved copper, however, undoubtedly depends on the character of the water, especially on the carbon dioxide and oxygen contents, and in unfavourable circumstances it would certainly be expected to reach higher figures. The character of the water also governs the time required for the formation of the protective film; it is a matter of experience that only a few weeks are necessary with hard waters, but with soft and especially with acid waters it may take months or years.

Systematic investigations of the relationship between the action of drinking water on copper pipes and the carbon dioxide and oxygen contents of the water do not appear to have been carried out. Some preliminary laboratory researches have therefore been conducted at the Norges Tekniske Hoiskole, Trondheim, with copper pipes and drinking water containing various additions, under stagnant conditions. The main objects of these investigations were to study the reactions governing the dissolution of copper and also to gain information concerning possible precautionary measures against attack of copper pipes by drinking water under service conditions.

Theoretical Considerations.—The corrosion behaviour of copper is influenced by the fact that it can be either mono- or divalent, that cupric oxide is rather easily soluble, and that both oxides have little ability to form protective films, as has been shown by Bengough and Hudson, Vernon, and others. Copper dissolves rapidly in oxidising acids, such as nitric acid and hot sulphuric acid. The rate of solution of copper in non-oxidising acids can be greatly increased by the presence of oxygen. It has long been known that, in the presence of metallic copper, cupric salts in oxygen-free solutions are gradually converted to more sparingly soluble cuprous salts. The same is true of oxides and hydroxides, so that in neutral solutions, in the presence of copper, cuprous oxide is always formed.

A higher concentration of dissolved copper than that corresponding with the solubility of cuprous oxide in oxygen-free solutions must, however, be reckoned with during the corrosion of copper by drinking water containing oxygen. As the oxygen is consumed during the corrosion process, the cupric hydroxide reacts with the metal, forming cuprous oxide, with the result that the concentration of copper in solution will decrease again to a value corresponding to the solubility of cuprous oxide. In acid solutions, the cupric ion concentration obtained in the presence of cupric hydroxide increases, due to the lower hydroxyl ion concentrations. A reduction of the copper concentration would be expected in weakly alkaline solutions as the *p*H value rises, so long as this is determined by the solubility of the hydroxides. This may not be the case, however, if complex ions are formed, as, for instance, when sodium bicarbonate is present in the water.

Determination of the Solubility of Copper Compounds.—Since the amount of copper dissolved by tap-water will be largely determined by the solubility of the corrosion products when the film has reached a stationary state, an experimental study of the solubility of various copper minerals and oxides in boiled distilled water, with and without carbon dioxide additions, has been carried out. The solubility experiments were conducted with 0·4 g. to 1 g. of various finely pulverised natural copper minerals in filled 120-ml. shaking cylinders. After 24 hours' shaking, at 20 deg. C., the solutions were titrated for carbon dioxide, then filtered, and the copper determined in the filtrates. The compounds investigated were cuprite, copper oxide, malachite, azurite, and atacamite. Apart from the cuprite, which contained a certain amount of free copper (this was unimportant since additions of copper filings were made to combat oxidation during the experiments), all the materials used were of high purity.

It was clear from the results obtained that the presence of free carbonic acid promotes the solution of the various copper minerals considerably. This agrees with previous results obtained in 1908 by Free in America, using malachite. Thus, the amount of copper dissolved in the tap-water from copper pipes with a protective coating of corrosion product will increase in the presence of aggressive carbon dioxide. Amounts appreciably greater than those reported by Haase* must be reckoned with for acid waters, especially if cupric compounds are formed, such as cupric oxide, malachite, azurite, or atacamite. Cuprous oxide, on the other hand, is considerably less soluble (about $\frac{1}{2}$ to $\frac{1}{10}$) than cupric oxide in water containing carbon dioxide. Consequently, dissolved oxygen in drinking water also promotes the dissolution of copper even in pipes with stable films, owing to the oxidation of cuprous to the more soluble cupric compounds.

Corrosion Experiments with Copper Tubes.—Copper tubes of 99·8 per cent. to 99·9 per cent. purity (from Finspong Metallverks Aktiebolag, Sweden) were used

* Paper presented for written discussion, *The Journal of the Institute of Metals*, January, 1940.

* See *Gas-und Wasserfach*, vol. 75, page 941 (1932).

† See *Répertoire de Pharmacie*, vol. 22, page 680 (1873).

‡ See *Z. Metallkunde*, vol. 26, page 185 (1934).

* *Loc. cit.*

in the corrosion tests. These showed no trace of oxides in the polarisation microscope. The dimensions of the tubes were: internal diameter 0·50 cm., length 500 cm., volume 99 cc., and internal surface area 785 sq. cm. Four tubes of each kind were annealed and bent into spirals of 18 cm. diameter. These were fitted vertically in a closed thermostat, with the upper ends protruding through the cover and the lower ends leading out through watertight rubber bungs in the base of the thermostat, so that they were accessible at both ends. The tubes could be closed at the lower ends with copper stop nipples, and at the upper ends with rubber tubes provided with glass ball valves. The solutions were introduced into the tubes from flasks which were coupled to the lower ends of the tubes by rubber connections.

The copper tubes were freed from annealing scale by treatment for several hours in 2*N*-ammonia solution at 20 deg. C., followed by washing with distilled water. This treatment was repeated until the same amount of copper was taken up by the water in each of the four tubes under identical conditions. The corroding solutions were made up from tap-water with various additions of oxygen, carbon dioxide, sodium bicarbonate, sodium hydroxide, and calcium oxide. The tap-water had the analysis:

Total solids	47·5 mg. per litre.
Ash	28·5 „ „
Chlorides as Cl′	9·5 „ „
Iron	0·07 „ „
Dissolved oxygen	10·8 „ „
Permanganate consumed ...	65 ml. of 0·01*N*-$KMnO_4$ per litre
Combined carbon dioxide ...	8 mg. per litre
Aggressive carbon dioxide ...	4 „ „
Ammonia, oxides of nitrogen, and phosphates	Not detected
*p*H	6·3

From 0·42 mg. to 0·78 mg., or an average of 0·60 mg., of copper per litre was dissolved by this water when it was allowed to stand for 24 hours in the copper tubes, after which time the maximum concentration of copper in solution has been passed. The results quoted below represent the mean of two or more experiments.

Effect of Bicarbonates.—Additions of sodium bicarbonate to the water increased the amount of copper dissolved in 24 hours (at 18 deg. C.), as shown in Table III. Since additions of sodium bicarbonate will cause an increase in the concentration of both bicarbonate

TABLE III.

Amount of Sodium Bicarbonate Added.	*p*H.	Copper Content of Water
Grm. per Litre.		Mg. per Litre.
0	6·3	0·6
0·1	7·0	1·0
0·2	7·1	1·2
0·3	7·15	1·8
0·4	7·2	1·9
0·8	—	2·2
1·2	—	4·5

and carbonate ions, it is natural to suppose, in view of experiments on the solubility of copper compounds, that complex cations and anions are formed. The presence of complex ions in sodium carbonate solution has previously been demonstrated, notably by Pickering.* Additions of sodium bicarbonate to water (particularly from 10 g. to 100 g. per litre) were also found to increase the solubility of malachite. An increase in the amount of copper in solution after 24 hours' contact at 18 deg. C. also occurred with additions of calcium bicarbonate, or, in other words, with increase in the combined carbon dioxide content of the water, as shown by Table IV. The increase in

TABLE IV.

Combined Carbon Dioxide Content of Water.	*p*H.	Copper Content.
Mg. per Litre.		Mg. per Litre.
107	6·75	3·2
138	6·8	2·0
207	6·9	8·1
283	7·0	11·0

the amount of copper in the water is again presumably due to the formation of complex ions.

Effect of Carbon Dioxide.—Increase in the carbon dioxide content of the water, as might be expected, resulted in an increase in copper content after 24 hours at 18 deg. C., in agreement with the increased solubility of malachite. The results again suggest the formation of complex ions (Table V). The large increase in copper content of the water from about 150 mg. of carbon dioxide per litre upwards is characteristic.

Effect of Hydroxyl Ions.—Experiments were conducted with tap-water made increasingly alkaline by additions of lime or sodium hydroxide. By plotting the copper content of the water in milligrammes per litre against the *p*H values after standing for 24 hours

TABLE V.

Aggressive Carbon Dioxide Content of Water.	*p*H.	Copper Content.
Mg. per Litre.		Mg. per Litre.
7·4	6·3	0·8
45·0	—	1·0
98·5	5·65	3·9
128·0	5·0	5·0
165·0	4·8	11·2
188·0	4·4	19·9
235·0	4·35	40·1
277·0	4·25	41·8

in copper pipes at 18 deg. C., it was revealed that, until the *p*H of the solution had increased to between 8 and 9, additions of lime and sodium hydroxide resulted in a decrease in the amount of copper in solution, presumably owing to a reduction in the concentration of bicarbonate ions. Further increase in the *p*H, however, caused an increase in the copper concentration, which is thought to be due to the formation of cuprite ions or of complex ions. The fact that additions of lime result in lower copper concentrations than those produced by sodium hydroxide is probably an indication of the greater protective nature of the surface film formed in the presence of lime.

Effect of Oxygen.—Preliminary experiments have been carried out in waters containing two different

TABLE VI.

Amount of Sodium Bicarbonate.	*p*H.	Oxygen Content.	Copper Content.
Grm. per Litre.		Mg. per Litre.	Mg. per Litre.
0·1	7·0	2·7	0·7
		4·6	0·8
		11·8	1·0
		26·2	1·1
0·5	7·2	2·7	1·1
		5·8	2·0
		11·4	(1·8)
		24·2	3·2

amounts of sodium bicarbonate and with varying oxygen contents. The estimation of oxygen in solution was carried out by Winkler's iodimetric method. The results obtained after the solution had been in the copper pipes for 24 hours at 18 deg. C. are given in Table VI. It will be seen from the results that the influence of surplus oxygen is relatively small, the slight increase of the copper content with increased oxygen being due to the oxidation of cuprous compounds.

Influence of Time.—Investigation of the manner in which the concentrations of oxygen and of copper altered with time revealed that the copper content reached a maximum after a certain period and then decreased asymptotically towards a limiting value. The maximum value in the closed copper tubes appeared after about 15 hours with the untreated water, and also with water containing bicarbonate additions. With water containing carbon dioxide additions, however, the maximum value was reached in as short

TABLE VII.

Time of Contact.	Copper in Solution, Mg. per Litre.		
	17 deg. C.	46 deg. C.	70 deg. C.
5 minutes	0·17	0·59	0·95
10 „	0·27	0·70	1·06
15 „	0·36	0·72	1·15
20 „	0·41	1·10	—
25 „	0·42	—	—
30 „	—	1·25	1·30
2 hours	0·80	1·32	—
5 „	—	—	1·95
15 „	1·65	1·87	—
24 „	1·30	1·32	—
48 „	0·64	—	—

a time as 2 hours to 3 hours. At the same time, the oxygen content of the water decreases asymptotically with the time of action towards a final value of 1·0 mg. to 0·3 mg. per litre, which is reached after 48 hours. The absorption of oxygen was slower with tubes employed in previous experiments than with freshly pickled tubes free from surface films.

The oxygen consumption during the initial stages is usually much greater than corresponds to the amount of copper in solution, 10 mg. of oxygen being equivalent to 80 mg. of cuprous oxide. Solid corrosion products must, therefore, be formed on the surface of the experimental tubes almost as soon as the solutions are introduced, except in the case of the most acid solutions. The total oxygen consumption corresponds to an equivalent uniform surface film of cuprous oxide of about 200 A. thickness. This also shows that quite small amounts of oxygen are sufficient to produce solid corrosion products and saturated solutions in normal tap-waters. The modifications of the surface during the corrosion process will also profoundly affect the amount of copper dissolving from copper pipes by tap-water under service conditions. Naturally, a film of difficultly-soluble cuprous compounds will be present, but, in the presence of oxygen, an oxidation of cuprous compounds to cupric compounds will take place, with a resulting increase in solution of copper. The copper content of the water will then be largely determined by its carbon dioxide content, and, with flowing water, conditions will ultimately be attained at which the rate of solution of the corrosion products is equivalent to that of formation. It is, however, clear that in weakly-acid, less-aggressive solutions the formation of fresh cuprous oxide at the metal surface will exceed solution and render possible, after a short time, the formation of a fairly effective protective film. In acid solutions, on the other hand, a much longer period will be necessary for the formation of such films.

It is possible that the oxide films may be converted to copper salts. Thus, in the presence of carbon dioxide there may be partial conversion to malachite; in media containing chlorides, atacamite can be formed; while in waters containing sulphates, basic sulphate films, which may contain other insoluble components such as calcium or magnesium carbonates, are liable to occur.

Influence of Temperature.—Since copper pipes find extensive application in hot-water systems, it is of great interest to examine the effect of temperature. Experiments were carried out at 46 deg. and 70 deg. C. in a manner similar to that previously described. Since the content of aggresive carbon dioxide and, to some extent, that of oxygen in the tap-water varied with the temperature, the results were reduced to a common basis for purposes of comparison. The corrected values for the copper content (in milligrammes per litre) with 7·2 mg. aggressive carbon dioxide per litre (*p*H = 6·3) are reported in Table VII.

It appears that the rate of reaction is appreciably increased at higher temperatures, which is of importance in installations with a rapid circulation. Analyses also showed that oxygen is consumed more rapidly at higher temperatures. In addition, the maximum amount of copper in solution is somewhat greater, and it is also probably reached somewhat sooner, in warm water. But as precipitation is also accelerated, the differences may be partially reduced with time. One would rather anticipate a reduction in solubility when all the oxygen is used up, as the equilibrium moves over towards the less soluble cuprous compounds at higher temperatures.

Tentative Practical Measures to Combat Solution of Copper.—Although the experiments described in this paper were not carried out over very long periods or with intermittent flow, as under service conditions, the results obtained enable certain suggestions to be made for reducing the cuprosolvent powers of domestic waters. The decisive factors of the corrosion process under slow rates of flow are certainly the oxygen and aggressive carbon-dioxide contents of the water. Other constituents probably play minor rôles. Oxygen is difficult to remove, but as regards carbon dioxide, treatment of the water with lime or magnesia to *p*H 8·5 may be advantageous. The necessary plant for carrying out this treatment can easily be arranged at the water reservoirs or by each individual consumer. As an example, 1,000 litres of the water used in the experiments described in this paper required an addition of only 8 g. of lime for the *p*H to be increased from 6·3 to 8·5. It should be observed, however, that the formation of a protective deposit on the tubes may not take place if the rate of flow of water is high. The critical rate will probably depend on the type of water, and it is proposed to carry out an investigation on this point.

THE ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—The Association of Supervising Electrical Engineers announce that the Highfield Shield for 1939 has been awarded to Mr. R. H. L. Andrew for his paper on "Artificial Lighting by Electricity." The second prize has been presented to Mr. A. E. Gregg for his paper on "Fractional Horse-power Motors," and the third to Mr. E. A. Fowler for "A Thesis on the Causes of Breakdowns on High-Tension Circuits for Luminous Discharge Tubes." The Shield was presented for competition by the late Mr. W. E. Highfield when president of the Association in 1923, and the competition has been held each year since that date.

* See *J. Chem. Soc.*, vol. 95, page 1409 (1909).

LABOUR NOTES.

Although official details of the proposals which the Minister of Labour and National Service has submitted for the consideration of the engineering and shipbuilding trades are not yet available, newspaper accounts of the various conferences which have taken place suggest that the progress of the negotiations is promising. Early last week, the Minister saw the engineering employers and discussed with them ways and means of carrying out the proposals embodied in his plans for the expansion of the armaments industry. On Friday, Mr. Ernest Brown—who was accompanied by representatives of the Service Departments and the executive committee of the Amalgamated Engineering Union, discussed the proposals, and at the close of the meeting it was authoritatively stated that great progress had been made towards the solution of the problems involved. The representatives of the Union offered a number of suggestions which the Minister undertook to examine, and further meetings are to be held to go into the details of arrangements on which there is agreement in principle. At a meeting, later in the day, with the engineering council of the Confederation of Shipbuilding and Engineering Unions, the Minister was assured, it is stated, of the co-operation of the unions in the Confederation to "the fullest extent."

The Minister of Labour and National Service has also put before a committee of the Confederation of Shipbuilding and Engineering Unions a statement of the Government's proposals for the increase of labour power in the shipbuilding industry. This was the first indication to the shipbuilding unions of the part which the Government look to them to take, in co-operation with the employers, for accelerating the output of ships. When the representatives of the Confederation have studied the Minister's communication, they will see the Minister again. In the House of Commons' debate on the Navy Vote, it was stated that 20,000 more skilled men were needed for shipbuilding.

At a meeting last week of the Emergency Engineering Trades Joint Council, an agreement was reached under which all adult skilled, semi-skilled and unskilled employees in industrial establishments of the War Office, Air Ministry and Ministry of Supply will receive a bonus increase of 5*s.* a week as from February 19.

An application for a wages increase of 10 per cent. for all employees in electricity generating stations and sub-stations, and on high-tension mains on the railways, was heard by the Industrial Court in London last week. The organisations submitting it were the Electrical Trades Union, the National Union of Railwaymen and the Amalgamated Engineering Union. The award will be announced later.

Under an agreement between the Ministry of Supply and the General and Municipal Workers' Union and the Transport and General Workers' Union, the wages of many workers in shell-filling factories will be increased as from February 4. Including the 5*s.* recently granted to the engineering industry generally, the new rates will be:—Men, non-graded, 59*s.*; Grade 3, 62*s.*; Grade 2, 64*s.* 6*d.*; Grade 1, 67*s.*; overlookers, 72*s.*; senior overlookers, 77*s.* Women, non-graded, 34*s.*; Grade 3, 36*s.*; Grade 2, 38*s.*; Grade 1, 40*s.*; overlookers, 44*s.*; senior overlookers, 48*s.* An additional 2*s.* 6*d.* a week is to be paid to workers engaged on high explosives. Apart from the engineering advance of 5*s.*, the increases given under the new scale range from 4*s.* to 16*s.* 6*d.* a week.

In 1939, there was an increase of more than 15,000 in the membership of the General and Municipal Workers' Union, bringing the total up to 467,000. According to Mr. Charles Dukes, the general secretary of the organisation, 7,000 of the new members are women, of whom there are now 55,780 in the union.

At the end of January, 3,477 members of the Boilermakers and Iron and Steel Shipbuilders' Society were "signing the books," as compared with 3,150 at the end of December. In January, the number of superannuated members decreased from 3,687 to 3,636, and the number of members on sick benefit increased from 963 to 1,498. In January, the expenses amounted to 4,125*l.* 15*s.* 5*d.*; in December, they were 4,422*l.* 16*s.* 4*d.* There was a net increase in the membership of 453.

The *Trade Report* of the United Patternmakers' Association states that, in January, there was an increase of 13 in the number of unemployed members, bringing the total up to 63, and also an increase of 111 in the number on sick benefit, bringing the total up to 349. The membership increased to 12,205. There are 678 superannuated members.

As in pre-war years, the Trades Union Congress is to continue to provide full-time residential scholarships tenable at Ruskin College, Oxford. For the year 1940-41, five such scholarships will be awarded. In previous years the scholarships have been for two years. It has now been decided, in view of the uncertainty of the times, to reduce the period for which the scholarships are tenable, but to increase their number. The scholarships awarded this year will, therefore, be tenable for one academic year, from October, 1940, to July, 1941. A special curriculum for one-year courses has been planned, and it has been so arranged that the work of the three terms will be more or less self-contained. If, therefore, a student taking up residence at the beginning of year finds himself unable to remain for the whole year, he will still have gained something from his period of residential tuition.

In previous years, awards have been made on the results of a written examination, plus evidence of attendance at adult education classes and of active interest in local trade-union affairs. Under present conditions, however, it is impracticable to hold the written examination, and applicants are, therefore, asked to submit two essays on certain specified subjects of a trade union and political character. The awards will be made on the basis of these essays plus the evidence of attendance at classes and of interest in union affairs. Each scholarship is of the value of 150*l.*, which is to cover fees, board and lodgings and a sum for the partial personal expenses of the student. In addition, it is estimated that a further sum of 25*l.* per student will be necessary to meet the total cost of the year. For further information regarding the scholarships inquiry should be made to Sir Walter Citrine, Trades Union Congress, Smith-square, London, S.W.1.

A Swedish Act of December 8, 1939, permits exemptions in certain circumstances from the provisions of the Labour Protection Act of 1931, which relate to the employment of women during the night. Under the 1931 Act, a woman employed in industrial work in an undertaking employing as a rule not less than ten workers, must be granted an uninterrupted nightly rest period of not less than 11 hours in every 24, and this period must include the hours between 10 p.m. and 5 a.m. The new Act provides that, in the event of war or the risk of war for Sweden, or other exceptional circumstances caused by war, undertakings which are engaged in the manufacture or preparation of articles needed for national defence may be granted exemption from this regulation in cases where such exemption is absolutely necessary.

Under Section 70 of the New Zealand Statutes Amendment Act of October 7, 1939, No. 39, provision has now been made for setting up a separate Court of Record to deal with workmen's compensation cases. The arbitration court will thus be free to devote the whole of its time to questions of wages and hours of work, etc., and a more speedy settlement of compensation claims will be secured. Workmen's compensation law in New Zealand is still based on the principle of employers' individual liability, insurance not being compulsory. Weekly pensions are granted for a limited period of not more than six years in case of incapacity, if the claim is not settled by a lump sum payment. In the event of death, a lump sum is paid to the dependents. Expenses of medical treatment are payable by the employer to the extent of 1*l.* in case of incapacity; if death ensues, burial and medical expenses up to 50*l.* are paid. Claims can be settled by agreement between the parties or, failing such agreement, before a magistrate's court in minor cases or before the arbitration court otherwise.

The weekly organ of the International Labour Office at Geneva states that a Uruguayan Decree of October 20, 1939, extends the provisions of the legislation relating to the allocation of a fraction of pensions, etc., to guarantee payments of rent. A Decree of November 30, 1938, had already laid it down that all persons in receipt of pensions would be included under those entitled to benefit under the provisions of the Act of December 15, 1936, relating to rent guarantees. This Act, which was promulgated in the *Diario Oficial* of December 26, 1936, provides that all public servants with at least three years' service and all retired public servants in receipt of pensions may apply for the rent of their personal dwelling to be guaranteed by the Treasury. The guarantee may not, however, exceed 40 per cent. or, in exceptional cases, 60 per cent. of the pay or pension of the person concerned. Rents guaranteed in this way are paid directly by the Treasury, which refunds the expenditure to itself out of the salaries or pensions payable to the persons concerned.

The Decree of October 20, 1939, relates only to officials and retired officials of the State electricity and telephone services. It authorises the management of these services to make the necessary deductions from the salaries or pensions of the staff to guarantee any purchases which the persons concerned have made from their co-operative society. The deduction may amount to not more than 50 per cent. of the salary or 30 per cent. of the pension.

A circular issued by the French Prime Minister lays down the conditions under which temporary staff is to be recruited for existing services and establishments and for new services. Without prescribing rigid rules of priority the strict observance of which might interfere with the operation of services, the circular states, it seems possible to indicate at least the order in which staff should preferably be recruited. As regards women, a prior right to employment might be given to the wives of mobilised men when such women are not in receipt of any remuneration in respect of their husband and are responsible for maintaining children or relatives in the ascending line. Next in order of preference would come the wives or daughters of men who fought in the last war, the daughters, or relatives in the ascending line, of mobilised men, and mothers with family responsibilities who are widows or divorced. In the case of men, a prior right to employment might be given, subject to vocational ability, to men disabled in the war, ex-servicemen and wards of the State, or the sons, under age, of mobilised men and ex-servicemen.

A Labour Code adopted recently in Bolivia establishes the 8-hour day and 48-hour week, but night work may not exceed 7 hours, and women and persons under 18 years may not work more than 40 hours per week. The labour inspectorate may grant permits for extra hours up to two per day. The work of persons of either sex under 14 years, except as apprentices, is prohibited, and with certain exceptions women and persons under 18 years may work only during the day. For equal work, no discrimination shall be made in pay because of sex or nationality. For overtime and for time worked on rest days double time must be paid. For night work done under the same conditions as day work the rate ranges from time and a quarter to time and a half, according to circumstances. Annual paid vacations after one year's service are required, as are also annual wage bonuses payable from profits.

Compensation for accidents is due only after the employee has worked for 14 days and if his disability exceeds 6 days. The maximum compensation, that for death or total permanent disability, is two years' pay. The worker's position must be held for him during either occupational or non-occupational illness, and he must receive full pay for a specified time. The employer must pay funeral expenses for persons whose death is due to accident or occupational disease. The organisation of craft, industrial, and company unions, under Government supervision, is authorised, but Government workers may not be organised into unions. In case of a labour dispute, conciliation and arbitration must be tried, and only if this fails may a strike be declared, and then only on a three-fourths vote of those in active service.

The code applies to all industries, including those of the State, except agriculture, for which special regulations are to be issued. For purposes of the law, "salaried employees" are construed to include all workers (such as bank employees) covered by special laws; foremen and watchmen are included with "wage earners." In no enterprise or establishment may the number of alien workers exceed 15 per cent. of the total, and the admitted proportion of alien workers shall include technicians only. The number of woman workers may not exceed 45 per cent. of the personnel of any establishment which does not by its nature require a higher percentage of women. Only Bolivians may perform the functions of director, administrator, councillor, and representative, in State institutions, and in private institutions the activities of which are directly related to the interests of the State.

Incorporated Municipal Electrical Association.—The Council of the Incorporated Municipal Electrical Association, Bush House, London, W.C.2, decided, at its last meeting, to hold the ordinary general meeting of the Association in London, on May 30. There will be no Convention this year.

MECHANICAL ENGINEERING IN POWER STATIONS.

FIG. 5. UPPER PART OF BAROMETRIC CONDENSERS, STUART-STREET, MANCHESTER.

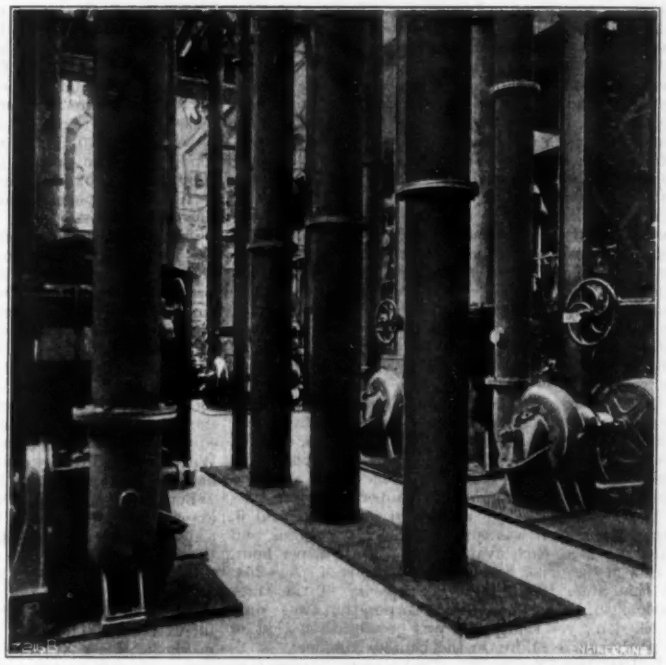


FIG. 6. LOWER PART OF BAROMETRIC CONDENSERS, STUART-STREET, MANCHESTER.

FORTY YEARS' DEVELOPMENT IN MECHANICAL ENGINEERING PLANT FOR POWER STATIONS.*

By SIR LEONARD PEARCE, C.B.E., D.Sc.

WHEN the Institution did me the honour of inviting me to give the Thomas Hawksley Lecture this year, it was but natural that I should choose as my subject that branch of engineering with which I have been most closely associated. In the time and space at my disposal it is desirable that I should deal chiefly with the main aspects of this development from the mechanical engineering point of view and select those features which will be of greater interest to the members of the Institution. This review will, it is hoped, summarise in some measure the trend of advancement and give an indication of the major progressions.

My association with the electricity supply industry dates back to 1897. At this date probably the majority of small continuous-current stations employed high-speed engines of the Willans or Belliss type, directly coupled to electrical generators. In the majority of alternating-current stations the prime movers consisted of slow-speed vertical or horizontal cross-compound engines driving the generators by means of belts or multiple ropes. Boilers of the Lancashire type were much in evidence, operating at pressures of 100 lb. to 150 lb. per square inch.

The Metropolitan Electric Supply Company was the first in the Metropolis to develop the use of the steam-turbine drive for electrical generators, and the reason was interesting. In 1893, the Manchester-square station contained ten Willans high-speed central-valve engines, exhausting to atmosphere through a 16-in. pipe carried to the top of the chimney shaft. Residents in the neighbourhood complained strongly of the noise and vibration of the engines and ultimately took legal proceedings against the company.

Elaborate and costly alterations were made to the foundations, but failed to overcome the nuisance. A solution was found by the adoption of turbine machinery. An order was placed with Messrs. Parsons in 1894 for a 350-kW single-phase turbo-alternator, running at 3,000 r.p.m. and generating current at 1,000 volts and 100 cycles per second. Soon afterwards, similar turbines were supplied to the Sardinia-street and Amberley-road stations, and Table I, herewith, shows the plants installed in the period 1894-1901. All these machines operated non-condensing with dry saturated steam at 150 lb. per square inch gauge. In the case of the 350-kW, 3,000-r.p.m., 50-cycle machines for Manchester-square, the guaranteed steam consumption with dry steam at 150 lb. per square inch was 41·3 lb. per kilowatt-hour, and for the 500-kW sets for Amberley-road the figure was 36 lb. per kilowatt-hour, the contract including a penalty of 50*l.* for each pound the steam consumption was in excess of this figure!

Power-station operation in those days was much more carefree and exciting than nowadays. Parallel operation of alternators with a periodicity of 83 cycles to 100 cycles per second presented difficulties and was not general practice. In changing over circuits from one machine to another it was not uncommon for lights to be put out. The boiler tubes often became choked and were cut out and replaced every three months, this being simpler than cleaning.

TABLE I.—*Parsons' Turbines Supplied to the Metropolitan Electric Supply Company*, 1894-1901.

Station.	No. of Sets.	Rating.	Speed.	Voltage.	Cycles per Second.
		kW.	R.p.m.		
Manchester-square ..	6	350	3,000	1,000	a.c. 50
Amberley-road	4	500	3,000	1,000–1,100	a.c. 50
	4	500	1,800	1,000–1,200	a.c. 60
Sardinia-street	7*	350	3,000	1,000	a.c. 50
	2	250	3,000	220	d.c.
	1	75	4,800	110	d.c.

* Later converted to 250-kW d.c. machines.

While the Metropolitan Company's plants were the first examples of the application of steam turbines for electrical generators in power stations in London they were preceded by plants installed elsewhere. The earliest instance was in 1888, when the Newcastle and District Electric Lighting Company ordered a non-condensing, 75-kW Parsons machine, running at 4,800 r.p.m. and driving a single-phase alternator supplying current at 1,000 volts and 80 cycles per second. Three similar machines were ordered by the same company shortly afterwards. Another famous example was the 100-kW Parsons radial-flow unit supplied to the Cambridge Electric Lighting Company in 1891, this being the first turbine to work condensing. It also ran at 4,800 r.p.m., with steam at 140 lb. per square inch dry saturated and a vacuum of 26½ in. of mercury, the full-load steam consumption being 37 lb. per kilowatt-hour. This machine is now to be seen in the Science Museum at South Kensington. The Newcastle-upon-Tyne Electric Supply Company (now the North-Eastern Electric Supply Company) was responsible for affording the opportunity for the size of steam turbine-driven generators to be increased, and in 1902 a 1,500-kW, 1,200-r.p.m. Parsons turbine was put into service at their Neptune Bank station.

The replacement of engines by turbines was, however, not generally the practice at the dates mentioned. The Wood-lane station of the Central London Railway, for example, which was opened in 1900, was equipped with the older type of plant. This railway was among the earliest to use electric traction, being preceded only by the City and South London Railway, opened in 1890, and the Waterloo and City line, opened for traffic in 1898. The prime movers consisted of six cross-compound Corliss engines, manufactured by Messrs. The E. P. Alliss Company, of Milwaukee. They were of the horizontal condensing type, each rated at 1,300 indicated horse-power and capable of working continuously at 1,950 indicated horse-power. The engines were supplied with dry saturated steam at 150 lb. per square inch and exhausted to jet condensers giving a vacuum of 26·5 in. of mercury, cooling towers being provided in conjunction with these condensers. The main generators were of the three-phase, alternating current type, each having an output of 850 kW at 5,000 volts and 25 cycles per second. A view of the engine room is shown in Fig. 1, page 254. Steam was raised in sixteen Babcock and Wilcox boilers, each capable of evaporating 12,000 lb. per hour, and fired by mechanical stokers. A view of the boiler house is shown in Fig. 2, page 254.

By 1903 or 1904, it was not unusual to install triple-expansion Willans and Belliss engines running at 150 r.p.m. to 200 r.p.m., and developing up to 3,000 indicated horse-power. Even larger sizes of slow-speed reciprocating and condensing engines were subsequently used; the following examples may be cited:—

The 5,000 indicated horse-power four-cylinder compound type engines built by Messrs. Musgrave for the Greenwich tramways power station of the London Council Council, comprising one vertical high-pressure cylinder and one horizontal low-pressure cylinder at each end of the crankshaft, with the generator between; the 4,000 indicated horse-power vertical three-cylinder compound engines—built respectively by Messrs. Musgrave and the E. P. Alliss Company for the Glasgow Corporation tramways station at Pinkston—running at 75 r.p.m., and directly coupled to 2,500 kW B.T.-H. generators; the 6,000 indicated horse-power vertical three-cylinder compound engines built by Messrs. Sulzer Bros. for the Bow station of the Charing Cross, West End and City Electricity Supply Company, and working at 160 lb. per square inch and 83 r.p.m.; and

* The 26th Thomas Hawksley Lecture, delivered before the Institution of Mechanical Engineers on Friday, January 19, 1940. Abridged.

the 7,000 indicated horse-power engines for the Stuart-street station, Manchester.

An association which was destined to extend over some 25 years commenced in the early part of 1901 with my appointment as Deputy Chief Engineer to the Electricity Department of the Manchester Corporation, which at that date possessed only one power station at Dickinson-street, from which supplies of low-tension direct current were afforded to the central area of the city. A second station was in course of construction at Bloom-street, to provide, *inter alia*, for the electrification of the city's extensive tramway system, while a third was planned on substantial lines for electrical supplies, on the high-tension alternating-current system, to the suburban areas. The Bloom-street plant and the initial installation at Stuart-street comprised slow-speed vertical cross-compound engines of some 2,500 indicated horse-power, the 1,500-kW electrical generators being placed between the high- and low-pressure cylinders. The steam pressure was about 160 lb. per square inch. An illustration of one of the Stuart-street generating sets, built by Messrs. Yates and Thom, is shown in Fig. 3, page 254. The magnet poles were mounted on the periphery of the flywheel, the combination running at 94 r.p.m.

The bedplates of these engines weighed about 19½ tons, the vertical standards 8 tons each, the crankshaft (which was 25 in. in diameter) about 16½ tons, and the flywheel (15 ft. 3½ in. in diameter) about 70 tons. The engines exhausted to barometric condensers arranged some 34 ft. above the tanks. The upper and lower parts of these condensers are illustrated in Figs. 5 and 6, page 263. Steam was supplied from 24 Babcock and Wilcox boilers, each evaporating 12,000 lb. per hour. A view of the boiler house is shown in Fig. 4, page 254. At this time, 1902, the total capacity of the three stations of the Manchester Corporation was only 26,550 kW, yet this figure was greater than that of any other undertaking in the United Kingdom.

In 1904, two 7,000 indicated horse-power marine-type triple-expansion four-cylinder vertical engines, running at 75 r.p.m., were installed. They were manufactured by the Wallsend Slipway and Engineering Company. Each was coupled directly to a three-phase alternator rated at 3,750/4,250 kW. The cylinders were 37 in., 59 in. and two 72 in. in diameter, and the stroke was 60 in. The crankshaft was balanced on the Yarrow-Schlick-Tweedy system. One of the engines is illustrated in Fig. 7, Plate XII. These reciprocating engines were the largest ever built in this country for any power station and probably constituted the high-water mark in the development of reciprocating steam engines for electrical generation. They were designed for steam at a pressure of 190 lb. per square inch, superheated to 500 deg. F., and exhausted to surface condensers giving a vacuum of 27 in. The diameter of the shaft was 30 in., and that of the rotating part of the generator 27 ft., the weight of the latter being 110 tons.

Soon after my appointment as Chief Engineer in 1904, it was decided that the time had come when the change-over from reciprocating engines to turbines should be made, and in 1907 a 5,000-kW Willans-Parsons reaction turbine was installed at the Stuart-street station, directly coupled to a totally-enclosed Siemens' three-phase alternator. This set ran at 1,000 r.p.m., and at that date was the largest plant installed in this country for electrical generation. An illustration of the set appears in Fig. 8, Plate XII. The turbine was designed for a pressure of 190 lb. per square inch and a total temperature of 500 deg. F., and exhausted to a Richardsons, Westgarth Contraflo 10,500-sq. ft. surface condenser. The steam-raising plant for the extensions comprised 12 Babcock and Wilcox boilers, each evaporating 20,000 lb. per hour, and the advent of further turbines rendered necessary the installation of additional boilers having a capacity of 40,000 lb. per hour each. This initial turbo-alternator installation was followed in 1907-14 by sets increasing in capacity from 6,000 kW to 15,000 kW. Speeds of 1,000 r.p.m. were not exceeded. The turbines were of the Zoelly design.

In 1914, I prepared designs for the erection of a fourth generating station by the Manchester Corporation at Barton, Trafford Park, which was to have an ultimate capacity of about 175,000 kW, and this station was scheduled to come into operation in 1917. Progress was interrupted by the war, and it was not until 1920 that work on the new station was commenced. In the meantime, further extensions were made to the Stuart-street station. Between 1917 and 1919, two additional units of the impulse-reaction type were installed, of 15,000-kW to 18,000-kW and 20,000-kW to 25,000-kW capacity, respectively, and running at 1,500 r.p.m. These showed a further advance in the rating of turbine-driven generating sets. The steam pressure was raised to 200 lb. to 210 lb. per square inch, and the total temperature was about 600 deg. to 650 deg. F. The turbines were supplied by Richardsons, Westgarth and Company, and the electrical generators by the British Westinghouse Company, now the Metropolitan-Vickers Electrical Company. The 25,000-kW machine is illustrated in Fig. 9, Plate XII.

Certain other notable additions have been made to the Stuart-street station in recent years, comprising 30,000-kW two-cylinder turbines running at 3,000 r.p.m., in association with water-tube boilers having an evaporative-capacity of 130,000 lb. per hour, while steam pressure and temperature have been raised to 375 lb. per square inch and 750 deg. F., respectively. A view of one of the recent 30,000-kW machines is shown in Fig. 10, Plate XII. The Stuart-street station, having an initial installed plant capacity of 9,000 kW in 1902, now has a capacity of 143,500 kW, a striking example of the advances which have occurred during the period.

The Barton station commenced operation in 1923. The initial installation comprised three Metropolitan-Vickers turbines of the single-cylinder impulse type, directly coupled to 27,500-kW alternators built by the same company. The steam pressure at this new station was 375 lb. per square inch at the boilers and 350 lb. per square inch at the turbine stop valve, with a total temperature of 700 deg. F. The plant operated with a vacuum of 29·1 in. and a final feed temperature of 200 deg. F. A view of one of the 27,500-kW sets is shown in Fig. 11, Plate XIII. The steam-raising equipment consisted of nine double-ended Babcock and Wilcox boilers fired by chain-grate stokers. Each boiler had a maximum evaporation of 100,000 lb. per hour.

Between 1928 and 1938, two further interesting extensions were made by Mr. H. C. Lamb, the present Chief Engineer to the Manchester Corporation Electricity Department. The first was a 41,000-kW turbo-alternator and three 130,000-lb. per hour boilers, working generally on the same conditions as the initial installation except that the final feed temperature was increased to 300 deg. F. A view of this plant is shown in Fig. 12, Plate XIII. This was followed by a 50,000-kW turbo-alternator, which constitutes the final addition to the station and raises its capacity to 178,000 kW. This last set was designed to operate with steam at the same pressure (350 lb. per square inch) as the earlier sets, but the steam temperature was increased to 825 deg. F. in accordance with latest practice.

In chronological order I should now pass to a matter which has had a considerable bearing on the design of power station plants. Owing to the non-compulsory powers vested in the Electricity Commissioners by the Electricity (Supply) Act, 1919, it was only possible to effect a limited measure of interlinking of generating stations by the setting up of Joint Electricity Authorities and Advisory Boards in various districts. It became obvious that further legislation would be necessary before complete and effective concentration of generating resources in the most efficient stations could be carried out. In 1925, therefore, the Government of the day appointed a committee under the chairmanship of Lord Weir, to consider and report on the future development of electrical generation in this country from the national standpoint. In 1926, the Electricity Supply Act was passed to give effect to the findings of the Weir Committee and to set up the Central Electricity Board. So far as generation was concerned, the main object of the Act was the selection, control, and interconnection, by means of a system of main transmission lines, of those stations—relatively few in number—which were best fitted to supply the electrical energy required by the nation with the maximum of economy.

The technical success of the scheme, therefore, rested on the assumption that the twofold savings effected in generation, due to the reduction in standby plant required and the high efficiency of operation of the selected stations, would more than compensate for the cost of the Grid. This has undoubtedly been realised. The reduction in the number of public power stations in this country has obviously had an important bearing on the design of the selected stations and the capacity and design of the plant installed in them, and has led to advances which might not otherwise have been made.

(To be continued.)

THE SOCIETY OF GLASS TECHNOLOGY.

At the meeting of the Society of Glass Technology, held in Sheffield, on Wednesday, February 21, 1940, three papers were presented and discussed. The first, "The Colour of Soda-Lime-Silica Glasses Containing Iron and Manganese Oxides," was by Mr. A. Lawton, B.Sc. Tech., and Professor W. E. S. Turner. The paper dealt with the effect of total and relative concentrations of iron and manganese oxides on the colour of commercial iron-manganese glasses. Extraneous factors influencing the colour of the glasses were kept constant. The glasses were melted in a small platinum crucible in a Silit-rod electric furnace, in a slightly oxidising atmosphere, for 22 hours at 1,400 deg. The glasses were of a composition derived from the formula: SiO_2 67 parts, Al_2O_3 2, CaO 10, Na_2O 15, Fe_2O_3 X, and MnO_2 Y; X and Y only were varied. Small discs were prepared, ground and polished to a thickness of 2 mm. to 3 mm., and their spectral transmission curves determined by means of a Bellingham and Stanley spectrophotometer.

Glasses Containing Iron Oxide.—A series of glasses containing from 3·10 per cent. to 9·62 per cent. Fe_2O_3 changed progressively from a green to a deep brown-green colour. The ratio of (FeO × 100) to the total iron expressed as Fe_2O_3 was nearly constant over this region, so that it appeared that the colour change was independent of this ratio and solely depended on concentration.

Glasses Containing Manganese Oxide.—These glasses were purple in colour and showed no colour change on increasing the manganese oxide content from 3·10 per cent. to 9·62 per cent.; the colour gradually became intenser.

Glasses Containing Fe_2O_3 + MnO_2.—With the compositions shown below, the colours were as indicated:—

Per cent. Fe_2O_3.	Per cent. MnO_2.	Colour.
3·10	—	Green.
2·06	1·03	Pale yellow green.
1·03	2·06	Pale yellow.
—	3·10	Purple.

Further series of glasses were prepared containing 4·08 per cent., 6 per cent., 7·84 per cent., and 9·62 per cent. of Fe_2O_3 + MnO_2, respectively. The changes in colour were similar to those given above, the colours changing from yellow or brown greens, through brownish yellow or amber colours to the deep purple of glasses containing only manganese oxide.

Glasses Containing Equal Proportion of Iron and Manganese Oxides.—For a given total concentration of iron and manganese oxides, the glass with the highest overall transmission was the one containing iron and manganese oxide in equal proportions. In a thickness of 2 mm. these glasses became opaque when they contained 10 per cent. Fe_2O_3 and 10 per cent. MnO_2. The transmission curves indicated the remarkable increase in transmission taking place when iron oxide was added to a manganese-oxide containing glass. The glasses which had a ratio of iron oxide to manganese oxide equal to 2 to 3, had the highest transmission of the glasses for a given total concentration of colouring oxides.

The second paper was entitled "Further Studies on the Influence of Sodium Chloride on the Iron Oxide Content of Glasses," and was by Mr. R. Halle, B.Sc. Tech., and Professor W. E. S. Turner. Previous investigations had shown that the Fe_2O_3 content was reduced to the extent of 9 per cent. of the original present in the glass by the addition of NaCl to the batch. The object of this investigation was to determine whether a further reduction of Fe_2O_3 content of glass could be obtained by adding to the chlorine-containing glass such volatile constituents as Se, B_2O_3 and $(NH_4)_2SO_4$. The melts were carried out in a gas furnace at 1,500 deg., melting in a platinum crucible enclosed in a sillimanite pot. The parent glass had a composition:—SiO_2 73·5, Na_2O 16·5, and CaO 10, with an Fe_2O_3 content of 0·08 per cent. The melting time was 4 hours after the last filling in, and the atmosphere in the furnace was slightly oxidising.

Owing to the variability of melting glasses containing volatile constituents, four types of glasses were investigated and four separate meltings of each were made under as nearly identical conditions as possible. The averages of each of these four melts of the four types were as follows:—

Glass.	Average Per cent. Fe_2O_3.	Average Per cent. Loss of Fe_2O_3.	Average Per cent. Loss of Cl_2.	Per cent. Accuracy in Reproducing Meltings.
Parent glass	0·080	—	—	± 0·6
,, $+Cl_2$* ..	0·071	11·3	18·5	± 2·5
,, $+Cl_2$+Se† ..	0·068	15·0	19·5	± 1·8
,, $+Cl_2+B_2O_3$‡	0·066	17·5	16·0	± 3·8
,, $+Cl_2+(NH_4)_2SO_4$§	0·057	28·8	23·5	± 2·3

* Cl_2 added as NaCl equivalent to 0·2 per cent. Cl_2 in the glass.
† Se added equivalent to 0·4 oz. Se and 1/12th of that amount of CaO per 1,000 lb. sand.
‡ Borax added equivalent to 2 per cent. B_2O_3 in the glass, giving a composition SiO_2 73·5, Na_2O 0·15, CaO 9·5, B_2O_3 2.
§ $(NH_4)_2SO_4$ added equivalent to 7·5 parts per 1,000 parts sand.

The effect of selenium was within the range of variability and so also was the effect of boric oxide; they consequently did not help materially in the removal of iron oxide from the parent glass. Ammonium sulphate, on the other hand, had a marked effect in reducing the Fe_2O_3 content.

MECHANICAL ENGINEERING IN POWER STATIONS.

(*For Description, see Page* 263.)

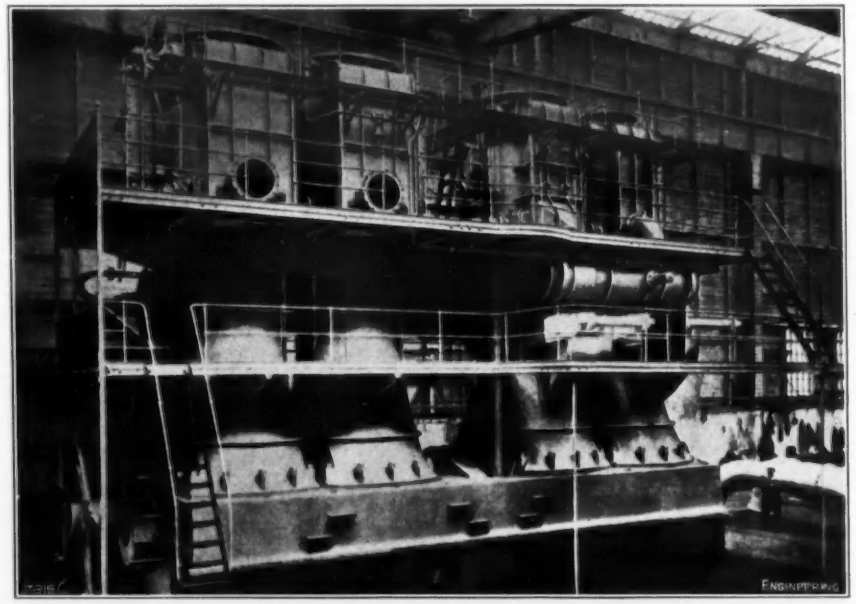


FIG. 7. 7,000-I.H.P. WALLSEND SLIPWAY ENGINES AT STUART-STREET STATION, MANCHESTER, IN 1904.

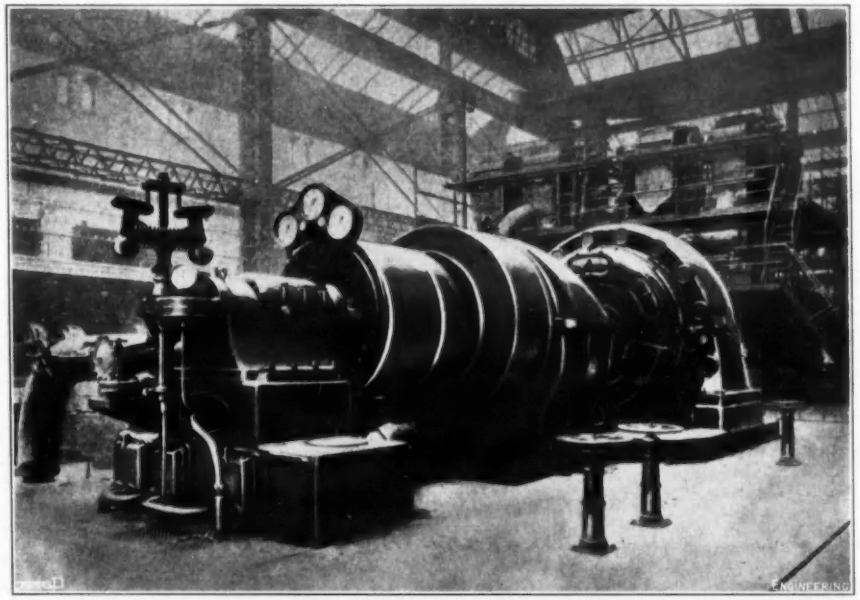


FIG. 8. 5,000-KW WILLANS-SIEMENS TURBO-ALTERNATOR AT STUART-STREET STATION, MANCHESTER, IN 1907.

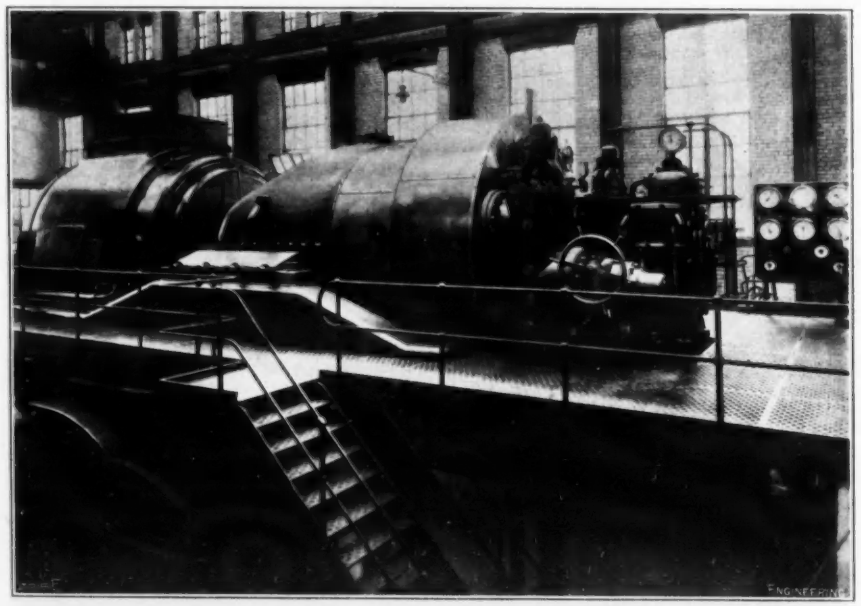


FIG. 9. 20,000-25,000-KW RICHARDSONS-WESTGARTH BRITISH WESTINGHOUSE TURBO-ALTERNATOR AT STUART-STREET STATION, MANCHESTER, IN 1918.

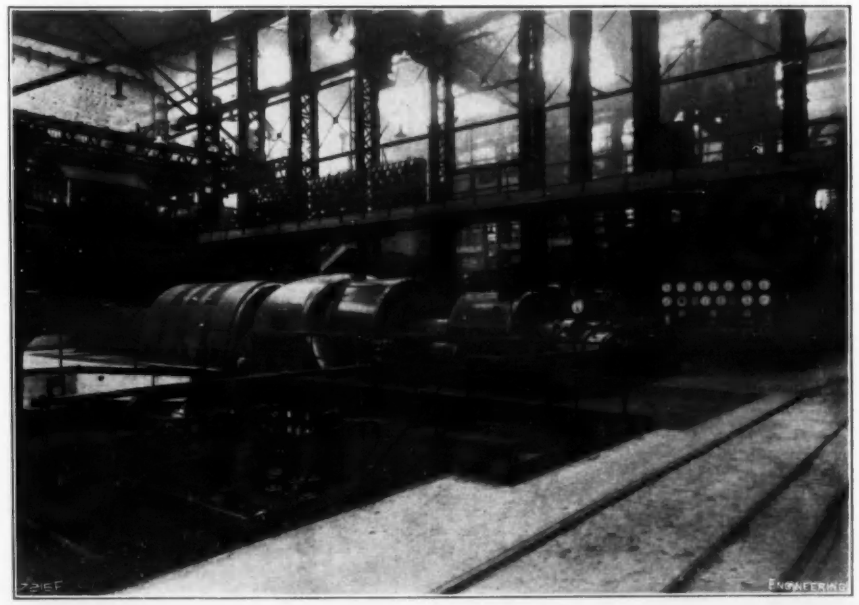


FIG. 10. 30,000-KW METROPOLITAN-VICKERS TURBO-ALTERNATOR AT STUART-STREET STATION, MANCHESTER, IN 1938.

(*To face page* 264.)

UNIV. OF MICH.

MECHANICAL ENGINEERING IN POWER STATIONS.

(*For Description, see Page* 263.)

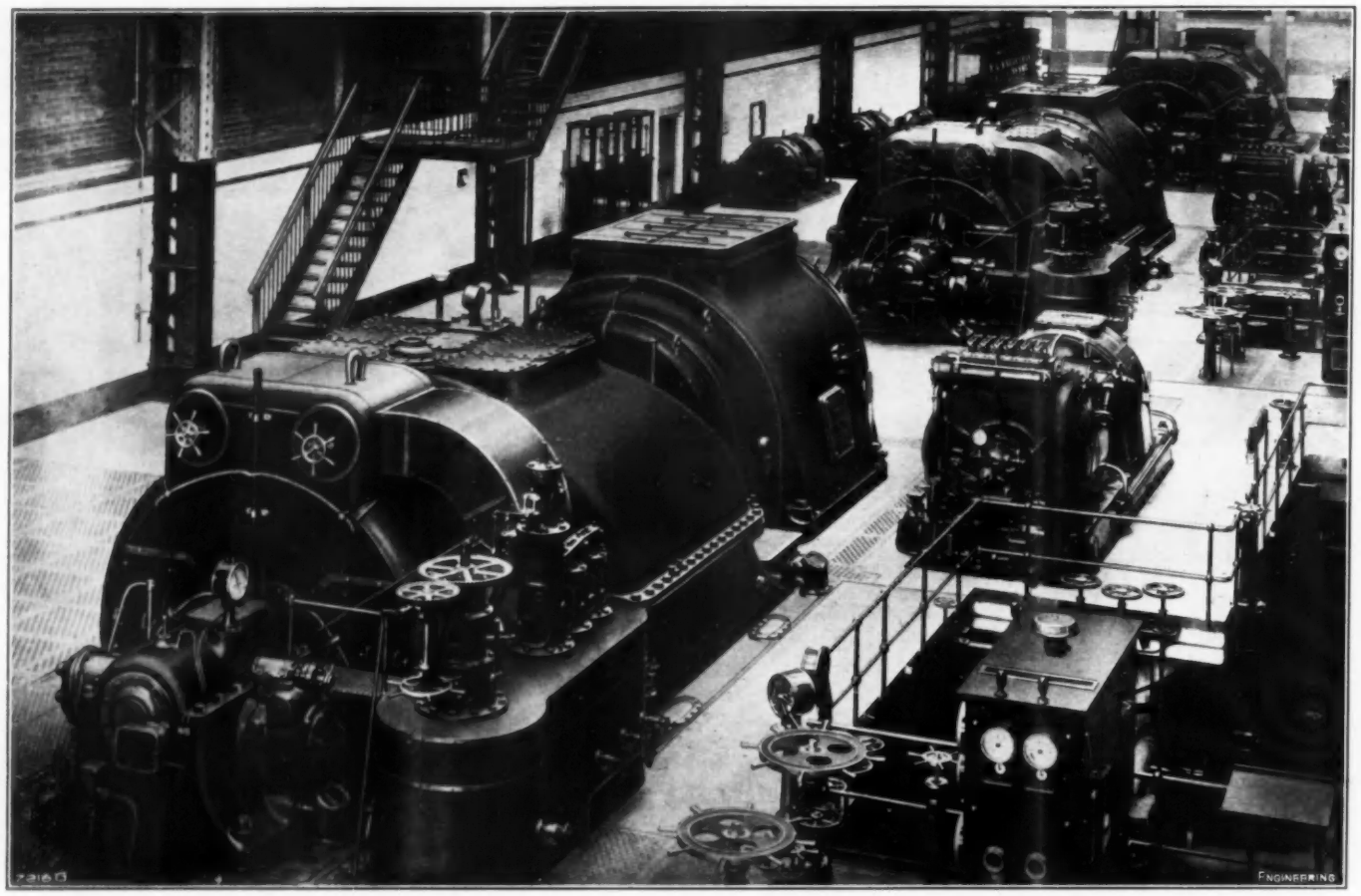


FIG. 11. 27,500-KW METROPOLITAN-VICKERS TURBO-ALTERNATOR AT BARTON STATION, MANCHESTER, IN 1923.

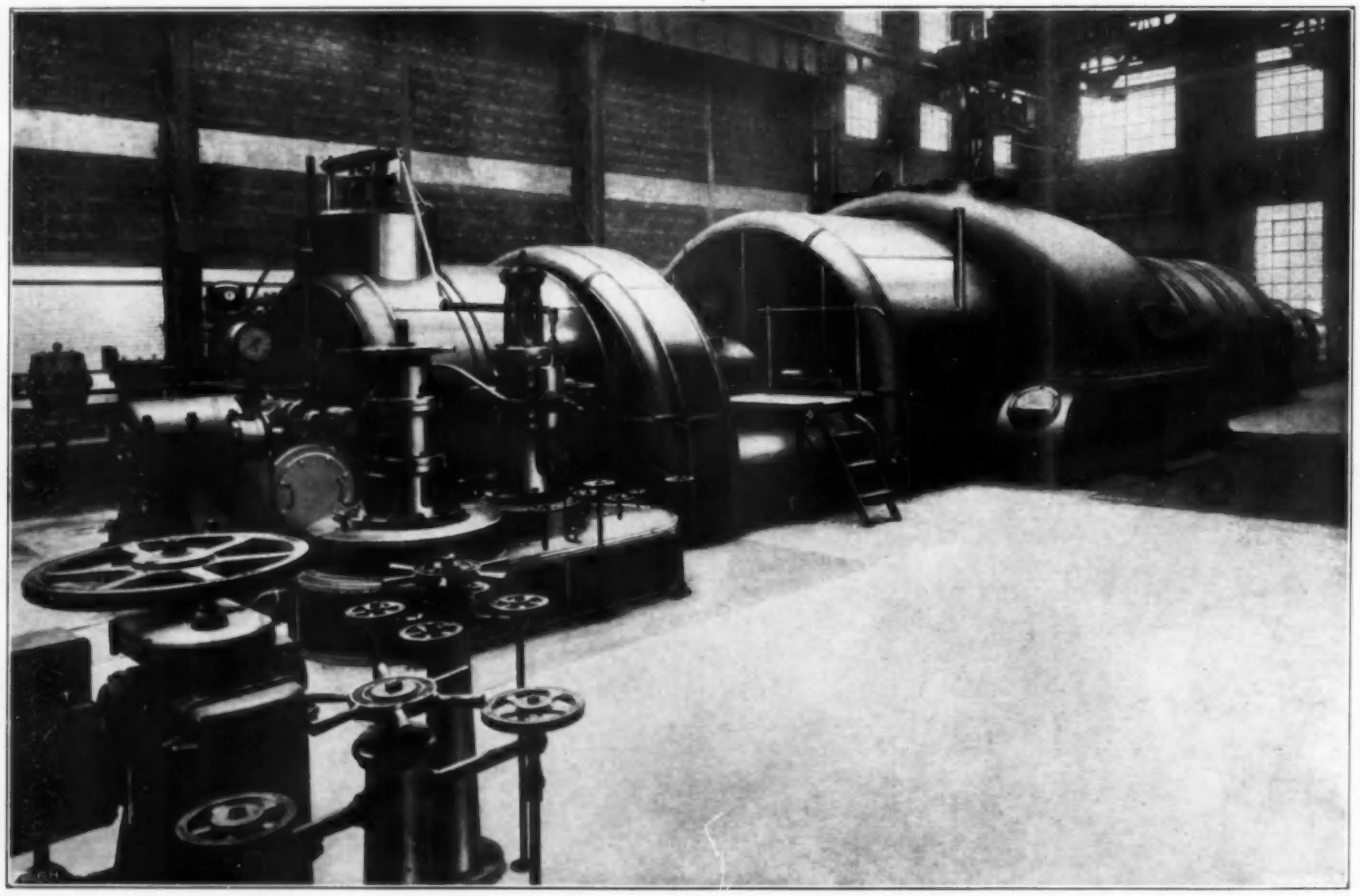


FIG. 12. 41,000-KW METROPOLITAN-VICKERS TURBO-ALTERNATOR AT BARTON STATION, MANCHESTER, IN 1928.

(*To face page* 265.)

THE "PISTONAIR" REVERSIBLE SINGLE-DRUM HOIST.

MESSRS. SULLIVAN MACHINERY COMPANY, LIMITED, GRANTHAM.

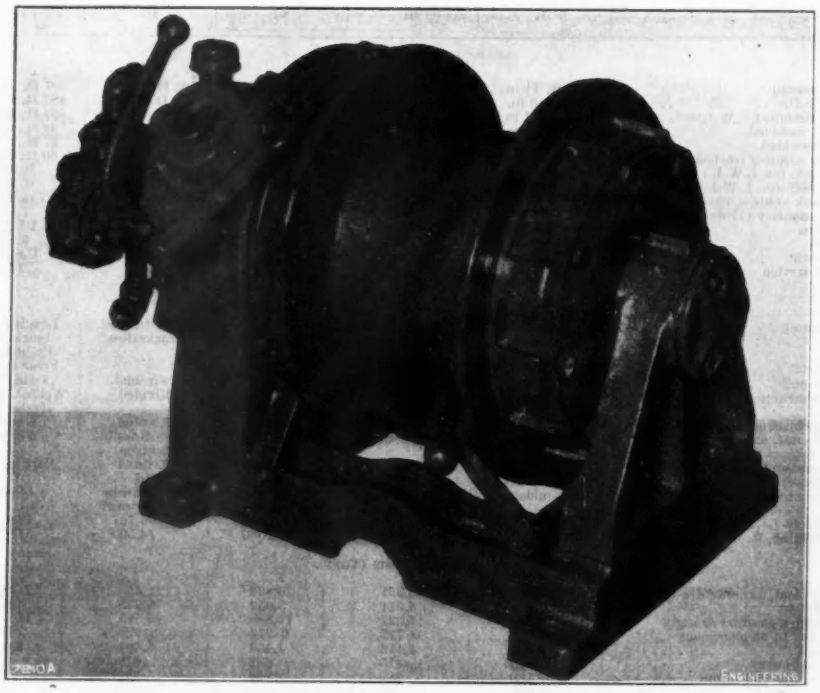


FIG. 1. HOIST WITH REVERSING CLUTCH.

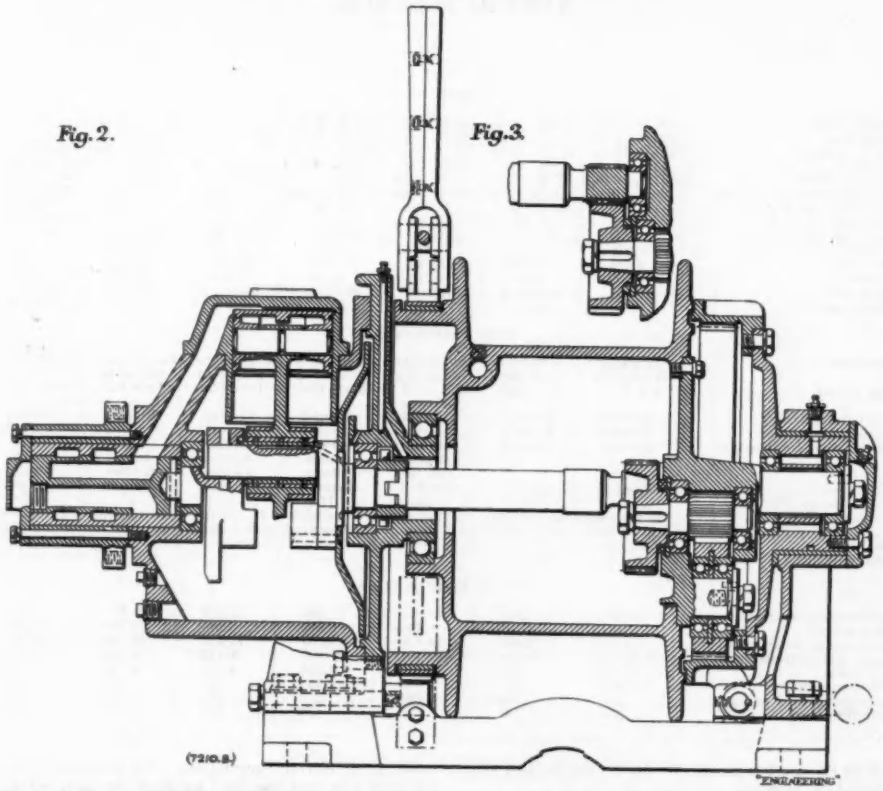


Fig. 2. *Fig. 3.*

The final paper, entitled "Transmission and Radiation Through Glass at High Temperatures. I. Transmission in the Visual Range up to the Softening Point," was contributed by Dr. A. J. Holland and Professor W. E. S. Turner. In it a detailed study was made on the transmission, for temperatures up to their softening points, of a number of commercial glasses. These included plate glass, white and pale-green bottle glasses, Pyrex and two high-temperature resistance glasses, four green and three amber glasses, and one blue bottle glass. Specimens were cut, ground and polished, placed in a small water-cooled electric wire-wound furnace, and the spectral transmissions measured at various temperatures on a spectrophotometer. It was found that for the colourless glasses, plate, white bottle glass, pale-green glass, Pyrex and resistance glasses, increasing the temperature brought about a reduction in the transmission, which was approximately uniform throughout the visual spectrum. For the green glasses, increasing the temperature reduced the maximum transmission and, at the same time, moved the position of the maximum transmission towards the red end of the spectrum.

For wavelengths greater than 0·63 μ the spectral transmission of iron-manganese and chrome glasses was increased with increasing temperature. Both iron-manganese and carbon-sulphur amber glasses showed a decrease in transmission with increasing temperature below this wavelength. The spectral transmission of the blue glass was decreased in the blue and red regions with increasing temperature, but increased in the green; thus the overall transmission of the blue glass for white light showed a slight increase with increasing temperature. The overall transmission of the remaining glasses tested decreased with increasing temperature, the decrease in transmission being approximately proportionate to the temperature. It was further found that increasing the temperature had the effect of moving the colour towards the red end of the spectrum, and, with the exception of the blue glass, making the colour more saturated.

"PISTONAIR" REVERSIBLE SINGLE-DRUM HOIST.

THE compact single-drum reversible hoist illustrated in the accompanying Figs. 1 to 3, is, as the name "Pistonair" indicates, driven by a compressed-air reciprocating engine. The hoist, when operating with air at a pressure of 80 lb. per square inch, will lift a load of 2,000 lb. at an average rope speed of 110 ft. per minute on an air consumption of 180 cub. ft. per minute. The drum is 11¼ in. in diameter by 8¼ in. long, and has flanges 18 in. in diameter, these dimensions giving a rope capacity, with $\frac{5}{16}$ in. rope, of 915 ft., with $\frac{3}{8}$-in. rope, of 640 ft., and with ½-in. rope of 365 ft. The safe maximum air pressure is 100 lb. per square inch. The hoist is manufactured by Messrs. Sullivan Machinery Company, Limited, Grange Works, Grantham, in collaboration with their works in the United States. As will be seen in the external view, Fig. 1, the controls are simple, the lever to the extreme left actuating the air-supply throttle valve, that to the right of it controlling the band brake, and that at the extreme right being the reversing lever, which operates by locking the castellated drum above it. An alternative type of reverse gear is a friction clutch instead of the more positive type shown. The overall dimensions are 34½ in. in length by 23 in. in width, and 20 in. in height. The weight is 480 lb.

Referring to Figs. 2 and 3, the engine is seen at the left-hand. There are four cylinders arranged radially and having their connecting rods bearing on a single crankpin. The big-ends are, thus, palm-shaped, and are held on to the pin by a pair of sleeves common to all four ends. The cylinders and covers are cast together, the latter being formed with a port continuous with that leading to the rotary distributing valve seen at the left and attached to the crankshaft. Both crank-webs are formed with balance weights and the shaft is mounted in ball bearings. The engine lubrication is of the splash type from the crankcase. The control throttle valve is of the disc type and is stated to be so airtight in all conditions of working that no shut-off valve is necessary on the supply pipe-line. The drum is mounted in ball bearings, directly at the engine end and on a spindle at the clutch end, the outer race of the latter bearing being carried in the clutch disc, which is mounted in a plain sleeve bearing. The right-hand end plate of the drum, on which the supporting spindle is formed, carries an epicyclic train, the pinions of which rotate in ball bearings. The inner pinion of the train meshes with a pinion integral with the driving shaft, as shown in Fig. 3, the output end of this shaft being supported in ball bearings on the centre line of the drum. The input end of the shaft is connected by a muff coupling to the crankshaft, a connection which enables the engine unit to be easily removed for inspection. The outer pinion of the epicyclic train meshes with internal teeth on the clutch drum.

It will be clear that, when the reversing lever is in the position shown in Fig. 2, the clutch is prevented from turning by a stop which enters one of the castellated notches of the clutch drum and, in consequence, the outer epicyclic pinion runs round the internal ring of this drum and the hoisting drum is rotated in a direction opposite to that in which the engine is running. When, however, the reversing lever is in the position shown in Fig. 1, the clutch drum is free to rotate, the result being that the winding drum rotates in the same direction as the engine, it being understood, of course, that the engine continues to run in one direction only. The brake is of the external contracting-band type. The operating lever is pivoted in a bracket attached to one end of the band, as shown in Fig. 2, and is connected by a link pivoted to a similar bracket on the other end of the band. Movement of the lever downwards from the position shown in Fig. 1, contracts the brake independently of the direction of rotation of the drum. The band is prevented from rotating by projecting fingers engaging with slots in brackets on each side of the frame. The frame is of cast steel and the hoist drum is of semi-steel. All gears and shafts are of heat-treated alloy steel. The bearings are of the Lubriseal type, and are protected against the entry of dirt. The engine unit is completely enclosed.

MODERN TANKER DESIGN.*

By N. J. Pluymert.

During the past eight or nine years many improvements have been made in the hull and machinery of tankers which have resulted in material benefits to the shipowner. The increased use of welding in hull construction has brought about a considerable reduction in steel weight, with a consequent increase in the vessel's deadweight. The change from low-pressure steam and Diesel to high-pressure steam-turbine drive has led to lighter machinery. In conjunction with these changes there has been a trend toward higher speeds and an increase in cargo deadweight.

A review of some designs of tankers built in recent years, all of nearly the same dimensions, shows the improvements accomplished both in construction and operation. About half of these designs are steam and the other half Diesel; half were built in the United States and half in Europe. Most of these vessels have now been in operation for a sufficient time to obtain accurate service data.

In Table I, herewith, are given the hull particulars of five different designs of steam tankers, all but one of which were built in the United States. The principal dimensions differ only slightly. All designs are on the longitudinal system of framing; some bracketed, some bracketless, the last using round-bar brackets and fluted bulkheads. The first two designs were entirely riveted, with the amount of welding increasing on each succeeding design. The last design has reduced the riveting to shell and main-deck laps only, with the deck longitudinal riveted to avoid overhead welding; the entire internal structure is welded, using fluted bulkhead construction.

Welding was employed on the first design to secure the ends of the longitudinals to the plating and thus prevent rivet leakage from excessive stress at this point. It was also used on later designs to weld the butts of the bottom plating, eliminating the inside butt straps, as this gave better drainage with consequent reduction in corrosion. The amount of welding was increased in the fourth design, D, principally in the engine room, where the double-bottom was of all-welded construction. The turbine and gear foundation were welded integral with the double bottom. This not only gave a saving in hull weight, but provided a more rigid foundation for the propelling machinery. Welding was also used in this design on the bounding bars of the oiltight bulkheads, eliminating liners and joggling of the bars. The bilge keel was also welded to the shell. The favourable experience with a conservative amount of welding on these tankers, and experience gained on the smaller tankers, led to the building of a practically all-welded 500-ft. tanker.

A study of corrosion in the various members of the tank structure indicated the advisability of eliminating pockets and horizontal members, where corrosion is accelerated by the collection of scale. The Bethlehem-Frear system was developed with the thought in mind of retarding corrosion, as well as saving weight by the use of fluted bulkheads. The latest design, E, with fluted bulkheads and a major use of welding, shows a saving of nearly 1,000 tons in the light weight of the vessel and a consequent increase in deadweight and earning power, with a hull structure less liable to rapid deterioration or corrosion. This saving was made by a reduction of 800 tons, or 18 per cent., in hull steel and 200 tons in machinery. The saving in hull steel was not accomplished by using the minimum permissible scantlings. The members at the top of the cargo tanks and the horizontal members carry the maximum of $\frac{1}{100}$-in. over classification scantling and the members in the centre of the tank are as much as $\frac{1}{50}$ in. over the minimum required scantling to allow for corrosion loss.

The hull particulars of four different designs of Diesel tankers are given in Table II, on this page; all but one of these vessels were built in Europe. The principal dimensions of all the designs are practically identical and compare very closely with the steam tankers. The use of welding on these designs is somewhat less than that on ships built in the United States. The first three designs, F, G, and H, are of riveted bracketless construction. Columns I, J, K, and L cover the last design, which is bracketed. The ships were built from the same plans in several different yards in Holland, Germany and Italy. The amount of welding in each of these designs differs, which accounts for some of the differences in the hull steel weight: J and L have more welding than the D steam design. When allowance is made for the additional steel for one bulkhead and summer tanks, the hull steel weight compares very closely with the D model. I is all-riveted and K has a small amount of welding. Comparing all the models illustrates the saving in steel accomplished by welding.

Particulars of the machinery, and trial and service data, for the steam and Diesel tankers, are given in Tables III and IV, respectively, on the opposite page. The first two designs of steam tankers used Scotch boilers and reciprocating engines, whereas the last three steam designs are turbine-driven through double-reduction gear, using steam at 400 lb. per square inch pressure and 720 deg. F. There is a reduction of approximately 200 tons in the weight of propelling and cargo-pumping machinery from the first two designs (A and B) with Scotch boilers, reciprocating engines and reciprocating auxiliaries, to the later models (C and D) with high-pressure steam-turbine drive and some electric auxiliaries. An additional saving of over 150 tons has been made in the last model, E, where the cargo pumps are electrically driven, allowing the elimination of a donkey boiler. The Diesel-propelled tankers show a machinery and cargo-pump weight that is at least 100 tons more than for the reciprocating steam-propelled ships and 450 tons more than the latest designed turbine drive. The steam group shows a progressive increase in speed for each new design and the Admiralty constant, which takes into consideration not only speed, but displacement and power, shows a betterment for each successive design. (Model B is not comparable, as this trial was run in deep water, while the other trials were in comparatively shallow water.) The Diesel group

* Paper presented at the annual meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1939. Abridged.

MODERN TANKER DESIGN.

TABLE I.—Steam Group.

Design	A.	B.	C.	D.	E.
Dimensions.					
Length overall	500 ft. 1½ in.	500 ft. 1½ in.	500 ft. 1½ in.	501 ft. 7½ in.	501 ft. 7½ in.
Length B.P.	480 ft. 0 in.	483 ft. 11½ in.	484 ft. 0 in.	485 ft. 6 in.	487 ft. 6 in.
Length, designed L.W.L.	494 ft. 11 in.	495 ft. 0 in.	495 ft. 2½ in.	497 ft. 6 in.	497 ft. 6 in.
Breadth, moulded	65 ft. 9 in.	65 ft. 9 in.	65 ft. 9 in.	68 ft. 0 in.	68 ft. 0 in.
Depth, moulded	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.
Draught, summer freeboard	28 ft. 10⅝ in.	29 ft. 6⅛ in.	29 ft. 10⅝ in.	30 ft. 0⅛ in.	30 ft. 0⅛ in.
Block coeff. (on L.W.L.)	0·75	0·753	0·748	0·739	0·739
Prism. coeff. (on L.W.L.)	0·768	0·768	0·763	0·754	0·754
Cargo tank volume, cub. ft.	651,230	669,778	711,642	736,636	751,753
Bunker capacity (17 deg. Bé oil)	1,800	1,825	1,385	1,315	1,765
Gross tons	9,154	9,767	9,512	9,860	10,222
Net tons	5,583	5,860	5,894	6,129	6,181
Where built	U.S.A.	England	U.S.A.	U.S.A.	U.S.A.
Entered service	1930	1931	1935	1937	1939
Hull Particulars.					
Construction	Longitudinal bracketless	Longitudinal bracketless	Longitudinal bracketless	Longitudinal bracketless	Longitudinal bracketed, Bethlehem-Frear system
Type of hull	C.L. bhd.	C.L. bhd.	C.L. bhd.	Twin bhd.	Twin bhd.
Shell construction	Riveted	Riveted	Riveted	Riveted	Welded, except strake laps
Interior construction	Riveted	Riveted	Riveted	Riveted	Welded
Interior ends, construction	Riveted	Riveted	Riveted	Welded double bottom	Welded
Deck construction	Riveted	Riveted	Riveted	Riveted	Part welded
No. transverse bulkheads	18	17	18	16	15
No. pump rooms	1—midship	2—midship and forward	2—midship and forward	2—midship and forward	1—aft
Total rivets	970,553	976,098	1,058,976	965,727	122,055
Total welding, ft.	—	—	12,000	14,500	371,168
Weight Analysis (Tons).					
Displacement, summer draught	20,316	20,951	20,832	21,450	21,503
Light weight	5,900	5,924	5,952	5,935	4,953
Deadweight, summer draught	14,416	15,027	14,880	15,515	16,550
Ratio, dw. to displacement	0·709	0·717	0·714	0·723	0·769
Hull steel	4,400	4,442	4,436	4,491	3,650
Wood and outfit	510	415	632	646	633
Cargo pumps and piping	180	285	254	190	80
Propelling machinery	810	782	630	608	590

TABLE II.—Diesel Group.

Design.	F.	G.	H.	I.	J.	K.	L.
Dimensions.							
Length overall	500 ft. 1½ in.	506 ft. 8 in.	505 ft. 2 in.	506 ft. 8 in.	506 ft. 8 in.	506 ft. 8 in.	506 ft. 8 in.
Length b.p.	480 ft. 0 in.	485 ft. 0 in.	485 ft. 0 in.	485 ft. 0 in.	485 ft. 0 in.	485 ft. 0 in.	485 ft. 0 in.
Length, designed L.W.L.	494 ft. 11 in.	496 ft. 9⅜ in.	497 ft. 9 in.	496 ft. 9⅜ in.	496 ft. 9⅜ in.	496 ft. 9⅜ in.	496 ft. 9⅜ in.
Breadth, moulded	65 ft. 9 in.	68 ft. 0 in.	74 ft. 10 in.	69 ft. 9 in.	69 ft. 9 in.	69 ft. 9 in.	69 ft. 9 in.
Depth, moulded	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.	37 ft. 0 in.
Draught, summer freeboard	29 ft. 0⅛ in.	30 ft. ⅜ in.	30 ft. 4¼ in.	29 ft. 10⅝ in.	29 ft. 11 in.	29 ft. 11 ⅜ in.	29 ft. 10⅝ in.
Block coeff. (on L.W.L.)	0·75	0·744	0·692	0·750	0·750	0·750	0·750
Prism coeff. (L.W.L.)	0·768	0·758	0·766	0·765	0·765	0·765	0·765
Cargo tank volume, cub. ft.	651,230	688,441	712,710	738,728	738,728	738,728	738,728
Bunker capacity (17 deg. Bé oil)	1,579	1,927	1,880	1,146	1,181	1,149	1,181
Gross tons	9,181	10,468	10,627	10,451	10,448	10,516	10,455
Net tons	5,599	6,127	6,202	6,054	6,054	6,077	6,068
Where built	U.S.	Germany	Holland	Holland	Germany	Germany	Italy
Entered service	1931	1935	1935	1937	1937	1938	1938–9
Hull Particulars.							
Construction	Longitudinal bracketless	Longitudinal bracketless	Longitudinal bracketless	Longitudinal bracketed	Longitudinal bracketed	Longitudinal bracketed	Longitudinal bracketed
Type of hull	C.L. bhd.	C.L. bhd.	C.L. bhd. arcform	Twin bhd.	Twin bhd.	Twin bhd.	Twin bhd.
Shell construction	Riveted	Riveted	Riveted	Riveted	Riveted	Riveted	Riveted
Interior construction	Riveted	Riveted	Riveted	Riveted	Part weld	Part weld	Part weld
Interior ends, construction	Riveted	Riveted	Part weld double bottom	Part weld double bottom	Weld double bottom	Weld double bottom	Weld double bottom
Deck construction	Riveted	Riveted	Riveted	Riveted	Riveted	Riveted	Riveted
No. transverse bulkheads	16	17	17	17	17	17	17
No. pump rooms	2—midship and forward	2—midship and forward	2—midship and forward	2—midship and forward	2—midship and forward	2—midship and forward	2—midship and forward
Total rivets	968,134	—	—	—	—	—	—
Total welding, ft.	None	None	—	—	—	—	—
Weight Analysis (Tons).							
Displacement summer draught	20,450	21,606	21,870	21,660	21,654	21,655	21,642
Light weight	5,844	6,201	6,450	6,593	6,240	6,492	6 297
Deadweight, summer draught	14,606	15,405	15,420	15,067	15,414	15,163	15,345
Ratio, dw. to displacement	0·714	0·713	0·701	0·695	0·712	0·700	0·709
Hull steel	4,434	4,602	4,817	4,936	4,551	4,701	4,428
Wood and outfit	532	548	503	531	556	668	544
Cargo pumps and piping	180	260	280	256	314	272	331
Propelling machinery	698	791	850	870	808	851	994

MODERN TANKER DESIGN.

TABLE III.—STEAM GROUP.

Design	A.	B.	C.	D.	E.
MACHINERY PARTICULARS.					
Type of propulsion	Steam-recip. quad. exp.	Steam-recip. quad exp.	Steam-turb. dbl. reduct. gear	Steam-turb. dbl. reduct. gear	Steam-turb. dbl. reduct. gear
No. of cylinders	4	4			
Size of cylinders	27 in., 39 in., 56 in. and 82 in.	27 in., 39 in., 56 in. and 82 in.			
Stroke	54 in.	54 in.			
Designed power	3,600 i.h.p.	3,600 i.h.p.	4,000 s.h.p.	4,000 s.h.p.	4,000 s.h.p.
Designed r.p.m.	75	75	75	75	75
Boilers, steaming	3 Scotch	3 Scotch	2-water-tube	2 water-tube	2 water-tube
Total heating surface	10,558·5	10,848	6,814	6,814	5,300
Working pressure, lb. per sq. in.	220	220	400	400	400
Temperature, deg. F.	382	382	720	720	725
Donkey boilers			1 water-tube	1 water-tube	
Type of cargo pumps	Recip.-steam	Recip.-steam	Rotary steam	Rotary steam	Main-Cent. strip-rotary electric
TRIAL DATA.					
Displacement	18,900	19,700	20,837	20,900	21,150
Draught	27 ft. 0 in.	27 ft. 10½ in.	29 ft. 10⅝ in.	29 ft. 3⅝ in.	30 ft. 1½ in.
Max. power	4,300 i.h.p.	4,103 i.h.p.	4,409 s.h.p.‡	4,585 s.h.p.‡	4,060 s.h.p.‡
R.p.m. at max. power	81·0	80·67	77·67	80·36	83·7
Speed at max. power	13·04	13·04	13·25	13·87	14·14
Speed at designed power (from trial curve)	12·28	12·45*	12·72	13·1	13·7
E.h.p. (model test) at designed power	2,759	—	—	2,625	—
Admiralty constant†	393	426	390	426	492
SERVICE DATA.§					
Power, average	3,084 i.h.p.	3,102 i.h.p.	3,678 s.h.p.	3,953 s.h.p.	4,014 s.h.p.
R.p.m. average	69·0	69·9	72·4	73·92	78·0
Speed, average	11·49	10·79	12·72	13·24	14·0
Fuel per day, average, tons	32·95	33·07	29·31	29·47	27·0
Cargo per round trip, tons	13,241	13,450	13,906	14,665	15,687
Average nautical miles per round trip	3,910	7,966	4,000	3,920	3,687
Average days per round trip	14·19	30·8	13·18	12·35	10·97

* Trials in deep water.
† Based upon standardisation trials. S.h.p. assumed 92 per cent. of i.h.p.
‡ By torsionmeter.
§ Service data are for round trips and are averaged for last three years or since commissioning. Performance is for sea passage, light-vessel to light-vessel.

TABLE IV.—DIESEL GROUP.

Design.	F.	G.	H.	I.	J.	K.	L.
MACHINERY PARTICULARS.							
Type of propulsion	Diesel 2-Cyl. Opd.-Piston, Sun-Doxford	Diesel 2-Cyl. Sgl.-Act., Krupp	Diesel 2-Cyl. Sgl.-Act., Krupp	Diesel 2-Cyl. Sgl.-Act., Krupp	Diesel 2-Cyl. Sgl.-Act., Krupp	Diesel 2-Cyl. Sgl.-Act., Krupp	Diesel 2-Cyl. Sgl.-Act., Fiat
No. of Cylinders	4	8	8	8	8	8	8
Size of cylinders	23·62 in.	25·59 in.	25·59 in.	25·59 in.	25·59 in.	25·59 in.	26·8 in.
Stroke	45·66 in.	49·21 in.	49·21 in.	49·21 in.	49·21 in.	49·21 in.	43·3 in.
Designed power	2,800 b.h.p.	3,600 b.h.p.	3,600 b.h.p.	3,600 b.h.p.	3,600 b.h.p.	3,600 b.h.p.	3,600 b.h.p.
Designed r.p.m.	80	110	110	110	110	110	110
Donkey boilers	One water-tube	3-Furnace Scotch	3-Furnace Scotch	3-Furnace Scotch	3-Furnace Scotch	3-Furnace Scotch	3-Furnace Scotch
TRIAL DATA.							
Displacement	19,028	21,350	21,150	21,490	21,490	21,275	21,380
Draught	27 ft. 2 in.	29 ft. 9 in.	29 ft. 6 in.	30 ft. 3 in. F.W.	29 ft. 9 in.	29 ft. 7 in.	29 ft. 6⅛ in.
Max. power	3,299 i.h.p.	4,200 b.h.p.*	4,220 b.h.p.*	4,849 i.h.p.	5,003 i.h.p.	5,431 i.h.p.	5,667 i.h.p.
R.p.m. at max. power	81·27	118·1	121·4	111·05	115·80	116	127·15
Speed at max. power	11·79	13·41	13·40	12·5	12·65	13·06	14·173
Speed at designed power (from trial curve)	11·64	12·43	12·76	12·05	12·13	12·46	13·25
E.H.P. (model test) at designed power	1,830	2,360	2.505	1,940	1,970	2,500	2,690
Admiralty constant†	401	411	441	371	384	476	500
SERVICE DATA.‡							
Power, average	2,821 i.h.p.	4,144 i.h.p.	3,969 i.h.p.	4,257 i.h.p.	4,218 i.h.p.	4,137 i.h.p.	4.100 i.h.p.
R.p.m., average	75·8	108·3	107	107·7	108	106·5	103·4
Speed, average	10·91	11·47	11·42	11·97	12·14	12·08	11·74
Fuel per day, average, tons	11·19	14·28	13·94	14·43	14·21	14·11	13·83
Cargo per round trip, tons	13,507	14,142	14,216	13,851	14,358	13,995	14,094
Average nautical miles per round trip	4,100	8,170	7,920	8,920	8,040	9,580	8,072
Average days per round trip	15·7	29·7	29·1	31·1	27·6	33·0	28·31

* Averaged by indicator and fuel consumption.
† Based upon standardisation trials. S.h.p. assumed 92 per cent. of i.h.p.
‡ Service data are for round trips and are averaged for last three years or since commissioning. Performance is for sea passage light vessel to light vessel.

shows an increase in horse-power in the later models over the earliest which is reflected in the better Admiralty constant.

The service data are based on performance both loaded and in ballast from departure to destination, over the last three years of the ship's service, or, where service has been less than three years, since going into service. Designs A, C, D, E and F are primarily operating in United States coastwise services with an occasional trans-oceanic voyage, whereas the other designs are operating entirely trans-oceanic. It is necessary to deduct one-half knot from the coastwise group, in comparing them with the trans-oceanic group, to compensate for the benefits of the Gulf Stream.

The steam group shows a marked fuel economy in the turbine drive in comparison with reciprocating engines. This is even greater in the latest design. Considered in conjunction with the greater deadweight of the later vessels, because of savings from welding, fluted bulkheads and lighter machinery, and increased speed from improved lines and smooth shell without butt straps, it can be seen that these factors reflect a major advantage to the owner. The service data of the Diesel group also show some increase in speed in the successive models. There is very little difference in the fuel consumption of these various models. The fuel consumption is just under one-half of that of the latest turbine vessel. This saving of 13 tons to 15 tons of fuel per day for Diesel vessels requires 30 to 35 days between fuelling ports to compensate for the 400 tons to 500 tons greater machinery weight. This greater machinery weight includes the necessary steam plant for steaming out cargo tanks, which is essential on Diesel tankers.

In considering new designs of tankers, attention must be given to the maximum use of welding in conjunction with a design of internal structure of the cargo spaces which will eliminate, as far as possible, horizontal surfaces and pockets, thus reducing corrosion. The type of machinery must be carefully considered for the intended service so that full advantage is taken of the lightest combined weights of machinery and bunkers. World tanker construction shows a decided increase in both speed and cargo deadweight in tankers built in recent years. Lighter and more efficient machinery and the higher deadweight efficiency of recent welded designs provide for these increases with little change in the principal dimensions.

CATALOGUES.

Tool Steels.—Messrs. Darwins, Limited, Sheffield, have sent us a booklet summarising the characteristics and treatment of their special steels for use at high cutting temperatures.

Foundry Equipment.—Messrs. Sterling Foundry Specialities, Limited, Sterling Works, London-road, Bedford, have sent us a catalogue of moulding boxes of various types and sizes, constructed of ribbed hot-rolled steel sections.

Rectifiers.—Messrs. Crypton Equipment, Limited, North Acton-road, Park Royal, London, N.W.10, have sent us a catalogue dealing with metal and valve rectifiers, which are supplied for battery charging, emergency lighting, cinema projection, etc.

Belt Shifters.—A brochure describing their safety deadlocking belt-shifting gears has reached us from Messrs. Henry Lindsay, Limited, 47, Queen's-road, Bradford. All the patterns listed comply with the requirements of the Factories Act, 1937.

Electric Heaters.—We have received from Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, a folder describing standard types of tubular electric heaters, intended particularly for use in shop windows.

Electric Lamps.—Messrs. E. K. Cole, Limited, Ekco Works, Southend-on-Sea, Essex, have published a brochure giving particulars and prices of "Sirius" lamps, which are available in six types, clear and pearl, suitable for 110 volts and 200/250 volts.

Boiler Grates.—We have received from Messrs. Patent Retorts, Limited, 5, Victoria-street, London, S.W.1, a folder describing the T.M.D. grate for steam generators. This grate was originally designed for heating shale retorts by burning the shale residue discharged after distillation.

Non-Ferrous Alloys.—Messrs. Tungum Sales Company, Limited, Iddesleigh House, Caxton-street, London, S.W.1, have sent us a brochure describing the uses of Tungum alloy. Physical and mechanical characteristics are given, and a particular feature is made of the corrosion-resisting properties of this alloy.

Valves, Cocks and Fittings.—Messrs. Newman, Hender and Company, Limited, Woodchester, Glos., have published a catalogue illustrating the use of hard stainless steels in their renewable-seated valves for steam pressures up to 350 lb. per square inch. Ammonia valves and controls for various purposes are also illustrated.

Rope Drives.—We have received a booklet containing a detailed description of their Vee-rope drives from Messrs. George Angus and Company, Limited, Angus House, Westgate-road, Newcastle-on-Tyne, 1. Useful information is included regarding the selection of the number and size of Vee-ropes for any particular drive.

Aircraft Bearings.—Messrs. Ransome and Marles Bearing Company, Limited, Newark-on-Trent, have published a useful list of ball and roller bearings which have been approved by the Air Ministry for use in aircraft. Prices, dimensions and tolerances are given in a catalogue which is notable for clarity and convenience in use.

Gasworks Plant.—Messrs. Ashmore, Benson, Pease and Company, Limited, Parkfield Works, Stockton-on-Tees, have sent us a catalogue describing gas holders, condensers, purifiers, producers and water-gas plant. Holders of the dry Klonne type, made by this firm, have now reached an aggregate capacity of nearly 21,000,000 cub. ft.

Electric Motors and Generators.—To replace obsolete sections of their main catalogue, Messrs. Higgs Motors, Limited, Witton, Birmingham, 6, have issued new sections dealing with their squirrel-cage low-starting current induction motors for 100 volts to 600 volts, 50-cycles, three-phase current. Motor-generator sets are also covered by the new lists.

Capstan Lathes.—Messrs. E. H. Jones (Machine Tools), Limited, Edgware-road, The Hyde, London, N.W.9, have sent us a folder describing the C.V.A. precision capstan lathe, which has 3¼ in. centres, a bed 3 ft. in length, a bar capacity of ⅝ in. diameter, and a speed range from 250 to 2,000 r.p.m. Another leaflet describes the Makonus electric pencil for writing on metal.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the communicators are given in italics.

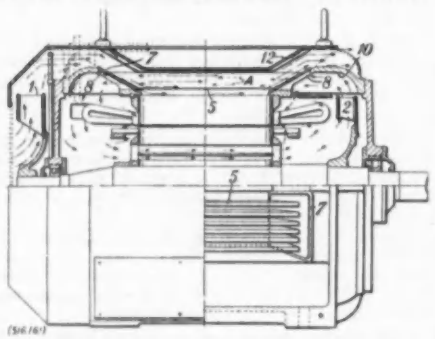
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. *each.*

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

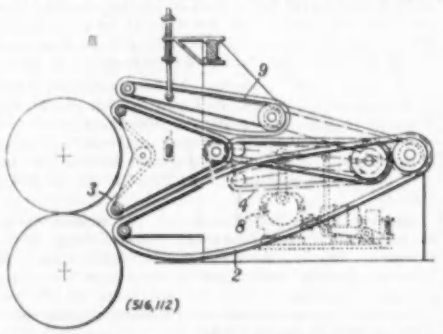
516,161. Totally-Enclosed Motor. The Harland Engineering Company, Limited, of Manchester, and L. Greenwood, of Stirling. (2 *Figs.*) July 26, 1938.—The invention is an arrangement of the cooling-air tubes used in fan-cooled totally-enclosed motors which gives a high thermal efficiency. The internal cooling air is circulated through tubes 5 extending lengthwise of the machine, the external cooling air being blown over the tubes and the stator periphery. The tubes are arranged in a series of units each consisting of a bank of straight



tubes 5 having sloping ends which merge into apertured plates 7. The plates are inclined to the tube axes and are seated on the boundaries of apertures 8 in the frame. The tubes are assembled with the plates to form the units which are mounted in position on the frame. The ends of the machine are connected together so as to form a separate and closed path for the internal air circuit. The fan 2 discharges into a pressure chamber 10 at the inlet ends of the tubes 5 and the tubes discharge at their exit ends over the stator end connections. The arrows A indicate the path of the air circulated by the fan 2. Cold air from the fan 1 is guided over the tubes and stator periphery by guides 12 which define an air path with unrestricted entry and exit but with sufficient restriction in the region of the stator to cause the air to scrub the tube surfaces and stator laminations. The tubes are oblong in cross section and brazed to the end plates 7. (*Accepted December* 22, 1939.)

MACHINE AND OTHER TOOLS, SHAFTING, ETC.

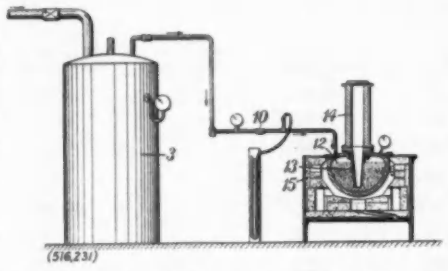
516,112. Rolling Mill. John Lysaght, Limited, and E. W. Plumley, of Newport (Mon.). (2 *Figs.*) May 19, 1938.—The invention is a two-high rolling mill in which the rolled sheet bar, after passing between the rolls, is returned over the upper roll to the front. Emerging



from between the pair of rolls, a sheet bar enters between the upper runs of a pair of endless chains 2 and the lower runs of a pair of endless chains 3. The bar emerges from between the runs while still resting on the chains 2. A pair of endless chains 4 are mounted on a pivoted frame below the bar, the frame being reciprocated vertically by an electric motor and a crank 8, and, in rising, picks up the bar. The chains 4 run counter to the chains 2 and carry the bar under a third set of chains 9 which lie above the upper run of the chains 3. The bar is then gripped by the chains 3 and 9, which bring it to the top of the upper roll where it is gripped by tongs. The motor driving the crank is controlled by flag switches in the path of the bar so that the frame automatically comes to rest at its lowest position and moves up when the bar has reached a predetermined position at the back of the rolls. (*Accepted December* 22, 1939.)

MINING, METALLURGY, ETC.

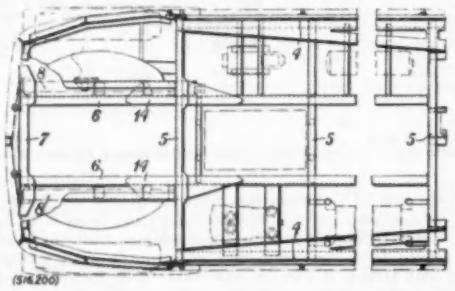
516,231. Casting Ingots. The Birmingham Aluminium Casting (1903) Company, Limited, and P. Pritchard, of Smethwick. (3 *Figs.*) June 18, 1938.—The invention is an apparatus for casting ingots by the process in which molten metal is forced by compressed air into a mould. It is particularly intended for casting uniform quality ingots of aluminium and aluminium alloys which are to be rolled. The casting apparatus consists of a pot 12 for the metal, an intake nozzle 13, a mould 14, and a furnace 15 for keeping the metal in the pot molten. The furnace is fired by gas burners. The nozzle 13 seals



against a seating on the pot and is joined to the mould by a spigot, the mould and nozzle being clamped to the pot by levers which have cam faces to engage a flange on the mould. Metal from a melting furnace is charged into the pot 12 and, by means of the furnace 15, is brought to a temperature suitable for the particular casting to be made. Meanwhile, a receiver, connected to the pot by a pipe and control valves, is filled with compressed air until the correct pressure is shown by a gauge. Air is then admitted to the pot at a rate which is carefully controlled by a needle valve 10 and forces the metal up into the mould without turbulence. Thus it is possible to fill the mould slowly so that the skin of oxide which forms on the surface of the metal rises and expands without breaking until the metal fills the mould, thus avoiding inclusions of oxide in the casting which occur each time the skin is broken. The metal continues to rise until it enters and seals the vent hole at the top of the mould. After this, the pressure in the pot increases to the receiver pressure. This pressure is maintained during the setting of the casting so that as the metal shrinks more is fed in, thus reducing the risk of piping. (*Accepted December* 28, 1939.)

MOTOR ROAD VEHICLES.

516,200. Omnibus Frame. London Passenger Transport Board, of Westminster, G. F. Sinclair, and H. J. Rivett, of London. (3 *Figs.*) July 15, 1938.—The invention is a forward anchorage for the front springs of a chassisless type 'bus which simplifies the frame construction. The under-floor framework consists of main longitudinal compound girders 4 with transverse cross bracers 5, to which are connected the two inner longitudinals 6. The



latter are continued forward to provide, in conjunction with the front bracers 5 and the short front cross member 7, a framework providing an anchorage for the front ends of the road springs 8. The rear ends of the springs are connected by shackles to the front bracer and are fixed at the front ends by a pin to the longitudinals 6. Where the vehicle is of the full-fronted body type, the front of the body and wheel arches are cantilever-supported by two minor longitudinals anchored to the gusset plates 14 of the inner longitudinals 6 at a point forward of the driving compartment bulkhead line. This cantilevered subframe also provides a mounting for the steering gear and driving controls. As a result of this forward extension of the under-floor frame, positive or negative springs can be employed without the necessity for upsweeping the longitudinals or shaping them specially to clear the springs, and the cantilever mounting of the front portion of the body gives considerable freedom from road and engine vibration. (*Accepted December* 27, 1939.)

RAILWAYS AND TRAMWAYS.

516,323. Overhead-Conductor Crossing. London Passenger Transport Board, of Westminster, and N. H. Thomas, of London. (3 *Figs.*) July 15, 1938.—The invention overcomes the danger of jamming of a burred collector shoe as it passes over the crossing. A narrow angle crossing has rigid track parts 4, 4′ and 5, 5′ aligned in pairs. The conductor wires are connected to their outer ends and the tracks are completed by the

Fig.1.

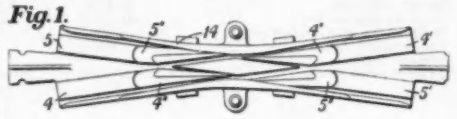
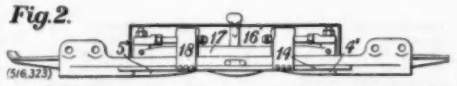


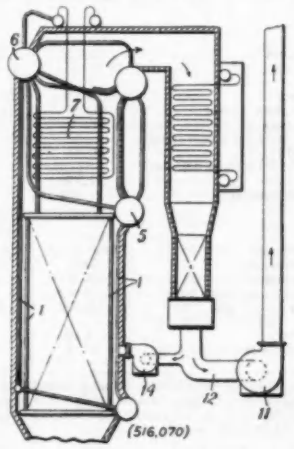
Fig.2.



movable tongues 4″ and 5″, and a stationary diamond-shaped centre. Operating rods, secured to each tongue pivot, are connected together by a substantial spring. Between the coupled pairs of tongues is an actuating rod which pivots about the centre so that when the rods are thrown over at one end of the crossing the other pair are thrown over in the opposite sense by the engagement of a collector shoe between the outer edge of the tongue 5″ and the side wall 14. The side walls are connected to a rib 17 on the body by springs 18, thus leaving the side walls free to yield. The springs 18 are of such strength that they do not yield instead of the tongues being operated. The casing 16 is a tight fit over the springs to give them support. (*Accepted December* 29, 1939.)

STEAM ENGINES, BOILERS, ETC.

516,070. Steam Generator. Marine and Locomotive Superheaters, Limited, of London, and L. C. Southcott, of London. (2 *Figs.*) June 20, 1938.—The invention is a method of increasing the final steam temperature in a steam-generating installation without increasing the rate of firing. The generating surface of the boiler is mainly constituted by the water tubes 1 lining the walls of the furnace chamber, and leading across the top from the water drum 5 to the steam and water drum 6. Above the furnace chamber is a convectively heated superheater 7, after which the gases heat a reheater, economiser and an air heater. After leaving the air heater, the gases



are drawn by the main fan 11 through the duct 12, whence they pass into the chimney. A fan 14 draws gases from the duct 12 and delivers them into the furnace chamber. The quantity of gas returned to the furnace chamber is regulated by varying the speed of the fan. In operation, the transfer of heat from the fresh gases to the tubes 1 is reduced, as the furnace temperature is reduced due to the admission of the returned products of combustion, but the weight of gases available to pass over the superheater elements 7 is materially increased, resulting in the required steam temperature being obtained without an excessive gas temperature at the superheater elements; also a higher reheat temperature is obtained. Control of steam temperature is effected by varying the quantity of cooled gases returned to the combustion chamber, the speed of the fan 14 being varied automatically according to the final steam temperature. (*Accepted December* 21, 1939.)